

GLASSHOUSE CROPS
RESEARCH INSTITUTE

ANNUAL REPORT

1957

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CONSTITUTION OF THE GLASSHOUSE CROPS RESEARCH INSTITUTE

The Glasshouse Crops Research Institute was established on the 8th September, 1953, as a company limited by guarantee, but without share capital, under the Companies Act of 1948. Its registered office is at Littlehampton, Sussex, where the main research station is being developed.

In the Memorandum of Association the principal object for which the Institute has been established is laid down as follows:

“To promote scientific research bearing on the cultivation of glasshouse crops and mushrooms, and of bulbs, flowers and shrubs grown in the open, and on matters ancillary thereto.”

The Institute is managed by a Governing Body consisting, at present, of fourteen members including the Chairman, Mr. T. Ainslie Robertson. Of these, six are well-known commercial growers who represent the branch of horticultural industry served by the Institute, and six are eminent scientists. The Governing Body is appointed by the Minister of Agriculture, Fisheries and Food, one of whose Senior Education and Advisory Officers is also a member.

The Institute is financed almost entirely by grants from the United Kingdom Treasury. From 1st April, 1956, these have been administered by the Agricultural Research Council which exercises general supervision over the Institute's staffing and research programme.

The Institute has a subscription scheme whereby growers may associate themselves with its work. For a small annual subscription growers obtain certain privileges which enable them to take a closer and more personal interest in the research that is being carried out on their behalf. Full particulars of this scheme may be obtained from the Secretary of the Institute.

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I. INTRODUCTION

The year was one of continued progress in the physical development of the Institute, the special experimental houses for the research departments being, for the most part, completed, and a start being made on buildings for mushroom research. While waiting for these new facilities to become available a full programme of experimental work was carried out in the trial glasshouses and in the old mushroom shed transferred from Cheshunt.

Governing Body

On his appointment to the Principalship of the University College of Ghana, Professor R. H. Stoughton resigned from the Governing Body and his place was taken by Professor J. P. Hudson, to whom we offer the warmest welcome. Professor Hudson, who has been appointed to the newly-created Chair of Horticulture at Nottingham University, tenable at the School of Agriculture, Sutton Bonington, is so well-known for his contribution to horticultural progress that he needs no introduction.

The Third Annual General Meeting was held on 2nd April, 1957, when the Chairman's Report and the Accounts and Balance Sheet for the year ended 30th September, 1956, were approved and adopted. Two ordinary meetings of the Governing Body for general business were also held during the year. The General Purposes Committee, formerly known as the Executive Committee, met twice to consider building tenders and other matters connected with the physical development of the Institute. The Research Committee met once to consider certain matters relating to the organization of research at the Institute, and on two other occasions to interview candidates for scientific staff appointments.

Staff

The Entomology Department was strengthened by the appointment of an additional entomologist to enable the Department to extend its work on mushroom pests. The new post was filled by Mr. I. J. Wyatt, B.Sc. (London), Dip.Agric.Sci. (Cantab), Dip.Trop.Agr. (Trinidad), who assumed duty on the 1st January.

Mr. J. H. L. Messing, of the Chemistry Department, was permitted to accept secondment to the Agricultural Department of British Guiana for about two years and left the Institute on the 10th October. His place was taken by Mr. G. E. Hobson, B.Sc. (Nott.), M.Sc. (Lond.), who was appointed on 9th September.

An offer of appointment as Statistician was made to, and accepted by, Mr. D. Cooke, of the National Vegetable Research Station at Wellesbourne. He will, however, be unable to take up the appointment until October, 1958, owing to a commitment to serve for a year as Visiting Professor at the Institute of Statistics, North Carolina, U.S.A.

A number of changes were made in the staff of Assistants (Scientific) and these are indicated in the staff list published at the beginning of this report. There was one change in the office clerical staff.

Five University students were given temporary employment during the summer vacation to enable them to obtain some experience of the Institute's work by assisting with the recording of the glasshouse experiments.

Capital developments

The building of the new research glasshouses was disappointingly slow, but those for the Chemistry, Crop Protection and Plant Pathology Departments became available for use towards the end of the year. The plant physiology house was nearing completion as the year closed.

Plans for the mushroom research unit were completed, and tenders were received and considered by the General Purposes Committee. It was subsequently found necessary to reconsider the design of the buildings, particularly with regard to the insulation and ventilation of the growing houses, and talks took place with the staff of the National Institute of Agricultural Engineering to decide the questions involved. The revised plans were in due course approved by all concerned, including the Mushroom Growers' Association's Research Sub-Committee, and a capital grant was received for the erection of the new buildings. Work started early in October, and good progress had been made by the end of the year. The new mushroom unit comprises two adjoining growing houses, each 31ft. 6in. by 15ft. 6in. internally, and these, together with the old Cheshunt house, provide a total of 2,000 square feet of cropping beds. In addition, there is a covered composting area, 69ft. by 24ft., which has been made large enough for any expansion of the growing facilities that may take place in the future. Attached to the composting shed are two small rooms for mixing and storing, and two small field laboratories, each 12ft. by 11ft., complete the composite building. A special feature of the new growing houses is the form of insulation, and it is hoped to achieve a U value of well under 0.2. The heating and ventilation arrangements are extremely flexible and should permit a very wide range of conditions for experimental study. The growing houses have been designed for use with trays, each 3ft. by 2ft., laid out in shelf fashion on steel racks; there are to be two sets of three tiers with a central gangway in each house. This arrangement of trays will allow considerable flexibility in experimental layouts.

Treasury approval in principle was given for the administration building, and the plans were completed in consultation with the architects. Tenders were invited, and were considered by the General Purposes Committee towards the end of the year. Most unfortunately this coincided with the very difficult financial situation in which the country then found itself, and which compelled the Government to impose restrictions on capital developments. As a result no grant for the building could be made at that time, and the indications were that the project might have to be held over until the Treasury 1959-60 financial year.

Two small capital grants were received for making concrete raised beds in one of the carnation houses and for building brick walls to demarcate experimental plots in the four aeroplane-type glasshouses constituting Block B.

Trial glasshouses

The Governing Body set up a sub-committee, consisting of four of its members and with power to co-opt outside experts, to consider modifications required to the heating system in the trial glasshouses in order to achieve greater uniformity, and to make recommendations. This matter was referred to in the previous report. The sub-committee met, formally, on three occasions during the year, and also paid a visit to the N.A.A.S. Experimental Horticulture Station at Stockbridge House, near Cawood, Yorkshire, to study the steam injection system installed there. Very careful consideration was given to a report received from Mr. E. R. Hoare, of the National Institute of Agricultural Engineering, on the functioning of the present system, with proposals for modifying it to meet the exacting needs of research. The Governing Body endorsed the sub-committee's recommendation that Mr. Hoare's proposals should be adopted, and the sub-committee then proceeded to consider details of the new scheme. Suggestions for the interim improvement of the present system while the new scheme is being planned and executed, were also under consideration at the end of the year.

Experiments in the trial glasshouses, 1957

The trial glasshouses are now made available to the research departments for experiments in connection with their programmes of research, and a full account of these experiments will be found in the departmental reports which follow.

Calibration of Blocks B and C

The calibration of the two blocks of aeroplane-type houses, Blocks B and C, was referred to last year. It was started as soon as the houses were ready for use in 1954, and complete yield data are available for both blocks for 1954 and 1955. In 1956 the work was discontinued in Block C and the houses made available for other experiments, but yield data are available for Block B for 1956 and 1957.

TABLE I
CALIBRATION OF BLOCK B
Average yield per plant per plot, 1957

Plot	House				Plot	House			
	1	2	3	4		1	2	3	4
	<i>lb.</i>	<i>lb.</i>	<i>lb.</i>	<i>lb.</i>		<i>lb.</i>	<i>lb.</i>	<i>lb.</i>	<i>lb.</i>
1	10.20	8.83	8.59	8.51	29	13.06	9.07	9.52	9.47
2	10.50	8.03	8.20	7.10	30	10.39	7.88	7.14	9.62
3	9.41	8.88	8.36	7.74	31	9.18	7.26	7.28	8.70
4	9.72	8.81	9.22	8.48	32	10.31	7.67	6.59	8.64
5	9.29	8.77	8.26	8.16	33	10.38	7.27	6.91	8.53
6	8.45	8.04	8.06	8.24	34	9.09	7.58	8.31	8.22
7	9.32	8.38	8.15	7.95	35	9.41	7.53	7.63	8.47
8	8.33	7.41	7.59	7.82	36	8.37	7.87	7.67	9.00
9	8.11	8.10	8.20	7.42	37	8.59	7.99	6.69	7.29
10	9.12	7.95	8.63	7.38	38	9.09	7.23	7.48	8.39
11	11.31	7.57	7.37	7.24	39	8.11	7.59	6.79	7.46
12	10.48	7.39	7.47	7.51	40	8.44	7.64	6.69	8.65
13	9.94	8.16	6.47	7.27	41	7.88	7.30	6.94	8.68
14	10.31	8.55	6.98	7.07	42	7.99	7.66	6.94	8.73
15	9.88	8.49	7.34	7.13	43	7.31	8.02	5.99	8.31
16	10.56	8.31	7.12	7.52	44	8.20	7.46	7.06	8.13
17	10.56	7.58	7.16	7.81	45	9.37	8.88	7.28	9.26
18	10.02	8.27	7.52	7.07	46	7.89	7.91	7.23	7.88
19	11.44	8.24	7.13	6.66	47	9.07	8.02	7.72	9.31
20	10.33	8.46	7.90	7.64	48	8.07	8.10	7.02	9.22
21	10.22	8.28	8.11	7.94	49	9.18	6.38	7.71	9.71
22	11.08	8.05	6.38	8.51	50	8.57	6.85	7.22	9.43
23	9.99	8.41	7.47	7.00	51	8.39	6.55	6.09	10.08
24	8.80	8.20	7.05	7.78	52	8.43	6.91	7.45	9.57
25	9.55	7.88	8.16	7.03	53	8.02	6.88	7.37	9.71
26	10.85	8.35	7.88	8.25	54	8.11	7.88	8.55	9.55
27	11.09	8.52	6.73	7.43	55	8.97	8.12	6.74	9.65
28	14.32	10.91	8.89	9.56	56	9.84	8.56	8.09	10.27

The object of the calibration was to determine the yield differences that occur in various parts of the blocks when cropped uniformly with tomatoes, and analyses of soil and leaf tissue samples were carried out to see whether these differences can be related to the composition of the soil or to certain chemical constituents of the plants. When the yield differences have been analysed statistically it should be possible to decide the best size of plot for future experimental work with tomatoes, and the observed yield differences may provide a useful guide to the layout of experiments.

Each block consists of four adjoining houses or bays. For the purpose of the calibration trial each house was divided into 56 plots, so there were 448 plots in the two blocks. With the exception of those at the ends of the houses each plot contained 10 plants in 1954, and 8 plants in 1955. The plots at the north ends of the houses, i.e., plots 1 and 56, contained 15 plants in 1954 and 12 plants in 1955, while those at the south ends, i.e., plots 28 and 29, contained 5 plants in 1954 and 4 plants in 1955. In 1956 and 1957, when yield recording was confined to Block B, all plots contained 8 plants.

As mentioned, the calibration of Block B was continued during 1957, and the houses were planted, with the variety "E.S.5" on 11th March. The crop from each plot was harvested and weighed separately, and the total yields, expressed as pounds per plant, are given in Table I. In looking at these yields it must be borne in mind that the manuring of the soil was very much restricted in order not to prejudice any future nutritional experiments that might be laid down in the Block. In 1957, stable manure at the rate of 40 tons per acre was dug into the bottom spit, and, with a view to improving the condition of the soil, rotted straw, at the rate of 20 tons per acre, was incorporated in the top spit by means of a rototiller. Dressings of base fertilizer were given at half the usual rate, and three top dressings only, were applied during the summer by means of an automatic diluter.

The Statistics Section at the National Vegetable Research Station very kindly undertook the examination of the yield data available for 1954-6, for both Blocks B and C, and arrangements were made for them to be treated on the electronic computer at Rothamsted. When the basic computations had been done, Mr. Cooke drew up a preliminary report on the information the yield data gave about the accuracy likely to be obtained in future experiments with plots and blocks of various sizes and shapes. He will continue his study of the data when he joins the Institute's staff.

Reserve land

In accordance with the policy decided upon by the Governing Body after consultation with the N.A.A.S. County Agricultural Officer, the reserve land was planted with spring-sown barley undersown with a grass and clover mixture. The season was a difficult one and the crop was poor, amounting, after drying, to no more than 0.69 tons per acre. Fortunately the undersown ley became vigorously established.

An area of some four or five acres, which will probably be required for the erection of glass-houses in the future, has been excluded from the farming programme and is to be levelled and laid down to grass.

The Institute occupies a very exposed site, and much damage to glasshouses has been sustained during south-westerly gales. Strong winds are experienced from many quarters and they must lead to excessive fuel consumption, especially during the winter and early spring. The provision of adequate shelter has therefore become an urgent necessity, but the problem is very much complicated by the need to avoid shading the glasshouses to any extent that would prejudice experimental work. The matter has been discussed with various experts, and advice was first received from the Forestry Commission's research staff as to the most suitable species for shelter belts under the conditions prevailing at the Institute. The siting of proposed belts was then discussed with Mr. W. H. Hogg, of the Meteorological Office's Agricultural Branch, to whom we are greatly indebted for his very careful consideration of the problem. The matter was in due course referred to the General Purposes Committee, and the main decision taken was to develop the existing hedge to the south of the Institute's land so as to give a double belt of trees,

of *Cupressus macrocarpa*, only, in front, and of mixed *macrocarpas* and *Pinus austriaca* behind. It may be necessary to restrict the height of this belt in places to avoid shading the glasshouses, but this problem will not arise for many years, by which time more may be known about the shelter problem and the value of light from low-angle elevations. As it will be a long time before any benefit is felt from the southern shelter belt, the provision of some form of temporary shelter, e.g., by means of wire-netting, is also being considered, not only to the south of the glasshouses but to the north and east as well. Wire-netting, of $\frac{1}{2}$ in. mesh, has already been erected at the south ends of the "valleys" of Blocks D and E glasshouses and seems to have been effective in reducing the breakage of glass in high winds.

Subscription scheme

A scheme to enable growers and others interested to associate themselves more closely with the Institute's work was drawn up, along the lines of the old Cheshunt Membership Fund, shortly after the Institute was established. The working of the scheme has been reviewed by the Governing Body, and some minor changes in the rules have been made. It is now referred to as the Subscription Scheme, as the use of the term "member" for subscribers is inappropriate under the Institute's constitution. The principal minimum subscription rates are five guineas per annum for firms or companies, and two guineas per annum for growers working on their own account or for other individuals interested. The main privileges for those subscribing are receipt of the Annual Report and attendance at the annual Open Day. After meeting the cost of these privileges the Scheme provides a small balance of funds which can be used to meet expenditure not covered by the Treasury grant made to the Institute for its normal working. The sums thus made available are applied to a "General Purposes Fund" which is under the control of the Governing Body.

Miscellaneous

Staff Association

The Staff Association has functioned well, and among other activities arranged very successful parties in mid-summer and at Halloween. A staff canteen at which a modestly-priced mid-day meal can be obtained has been organized and has proved popular. A Horticultural Society, supported by all grades of staff, has flourished, and two successful shows were held during the summer, as well as an allotment competition.

Liaison

The Director continued his membership of the various committees listed last year and also attended meetings of the Glasshouse and Flowers Working Parties of the Agricultural Improvement Council. He was also invited to serve on the N.F.U's Horticultural Development and Education Sub-Committee, and accepted the Chairmanship of the N.A.A.S. Glasshouse Group in succession to Mr. T. E. Pearson. Dr. Winsor, Head of the Chemistry Department, attended two meetings of the Bulbs Advisory Panel of the N.A.A.S. Kirton Experimental Husbandry Farm in Lincolnshire. Mr. Read, Head of the Crop Protection Department, represents the Institute on the Horticultural Section of the N.A.A.S. Regional (S.E.) Experiments Committee.

The strong liaison between the Institute and the National Agricultural Advisory Service has been maintained.

Open Day

The Institute's first regular Open Day was held in excellent weather on 12th June. Over 130 visitors attended, many of them growers from various parts of the country. There was also a

strong contingent of advisory officers and a number of scientists from other research establishments. The laboratories were made open to visitors in the morning, and the glasshouses in the afternoon. At lunch, after welcoming remarks from the Chairman of the Governing Body, the Director gave a report on the progress being made with the development of the Institute and on some of the main features of the research programme.

Other contacts with growers

The Director and various members of the staff paid a number of visits to commercial nurseries and mushroom farms to maintain the Institute's contact with the industry.

Of particular interest was a joint meeting with the West Sussex Tomato Working Party held at the Institute on the 17th January, when members of the research staff participated in a very useful discussion with prominent local growers, advisory officers, and others, of some of the problems of tomato cultivation.

The Mushroom Growers' Association's Research Sub-Committee met at the Institute in December, and this provided a useful opportunity of reviewing the progress of mushroom research to date.

Conferences

The Institute was invited to take one of the sessions at the N.A.A.S. South-Western Province Horticultural Officers' Conference and Refresher Course which was held at Wye College on 3rd and 4th January. Papers were presented by Drs. Leonard and Cooper of the Plant Physiology Department, and by Dr. Winsor of the Chemistry Department.

The Institute was well represented at the Fourth Easter School in Agricultural Science held at Sutton Bonington on 15th-17th April, the Director and three senior members of the staff attending. The subject of the conference was "Control of Environment in Crop Experimentation" and was of particular interest in connection with possible future developments in the Institute's research programme.

A strong team represented the Institute at the mushroom growers' refresher course, arranged by the Mushroom Growers' Association, which was held at Southport on 2nd and 3rd October. Papers were read by Dr. Hussey and Mr. Wyatt of the Entomology Department, and by Mr. Flegg and Miss Gandy of the Chemistry and Plant Pathology Departments.

Miss Gandy was also invited to present a paper on mushroom diseases at the first conference of the Horticultural Section of the Agricultural Association of Ireland held in Dublin on 12th to 15th November.

Dr. Hussey attended the N.A.A.S. Advisory Entomologists Conference on 28th and 29th November.

Shows

The Institute did not this year exhibit at the Chelsea Flower Show, but an invitation was received to exhibit at the Sussex County Agricultural Society's Show held at Bognor Regis on 17th-18th July, and this was accepted.

Talks by staff

Mr. Read gave a talk on the Institute to the Littlehampton "Round Table" on 10th October. Dr. Cooper gave an illustrated lecture on the Institute's work to the Reading University Horticultural Club on 22nd November.

Director's visit to U.S.A.

The Director was absent from 2nd October to 20th November for a visit to the United States in which country he spent just over five weeks, travelling from coast to coast. Detailed arrangements were made by the office of the Assistant Agricultural Attaché at the British Embassy in Washington, and among the places visited were:—

Plant Industry Station, Beltsville.
Pennsylvania State College of Agriculture, University Park.
Ohio Agricultural Experiment Station, Wooster.
College of Agriculture, University of Wisconsin, Madison.
College of Agriculture, Colorado State University, Fort Collins.
College of Agriculture, University of California, Berkeley.
College of Agriculture, University of California, Los Angeles.
Earhart Research Laboratory, Pasadena, California.
Western Washington Experiment Station, Puyallup, Washington.
College of Agriculture, Cornell University, Ithaca.
Rockefeller Institute for Medical Research, New York.

Visits were also paid to seed firms and suppliers of ornamental planting material, as well as to many growers' holdings. Particular attention was paid to the mushroom industry around Kennet Square in Pennsylvania, and to the carnation industry around Denver, Colorado. Contact was made with a number of growers' organisations.

Other visits

The Director and the Plant Breeder, Mr. L. A. Darby, visited nurseries in Lancashire on the 19th/20th March to see lettuce growing and to learn something of the requirements of the crop in that area. The opportunity was also taken to visit two mushroom farms.

The Director visited Guernsey on May 28th/29th and saw a representative cross-section of growers' holdings, both large and small. He was most hospitably received by the Guernsey Growers' Association, and Mr. J. G. Gillow, of the States of Guernsey Horticultural Advisory Service, was also most helpful. Contact was also made with the Guernsey Tomato Marketing Board. Much useful information was obtained about the Guernsey tomato industry and its problems.

Arising out of this visit it was thought desirable that Mr. P. H. Williams, the head of the Plant Pathology Department, should also pay a visit to the island to study disease problems, particularly wilt diseases of the tomato, which are prominent in some of the smaller holdings. Mr. Williams was in Guernsey on July 2nd and 3rd.

The Plant Breeder, Mr. L. A. Darby, visited the N.A.A.S. experiment stations at Woodthorne, Staffordshire, and Fairfield, Lancashire, towards the end of June, to observe the progress of trials of tomato hybrids bred for *Cladosporium* resistance. He also took the opportunity of visiting the National Vegetable Research Station at Wellesbourne for further discussions on lettuce breeding.

In December, Dr. Cooper, of the Plant Physiology Department, spent two days at Wye College in studying techniques used in Professor Wain's laboratory for the bio-assay of growth regulating substances. This was in connection with the Department's work on the growth trends in the tomato plant.

Visitors

The Institute continues to receive a considerable number of visitors, many of them from overseas. The number of visitors who attended the Open Day has already been mentioned. Among organised parties visiting the Institute were the N.F.U. 'Glasshouse Produce Committee, the Nazeing and District Growers' Discussion Group, a party of Dutch growers, the Bognor Regis Natural Science Society, members of the Felpham and Rustington branches of Toc H, students from the Worthing Technical Institute and senior girls from the Brighton and Hove High School. Overseas visitors included the following:—

<i>Australia:</i>	Mr. B. S. Janes, Senior Mycologist at Merrindale Biological Research Station, I.C.I.A.N.Z., Melbourne.
<i>British West Indies:</i>	Professor F. Hardy, Imperial College of Tropical Agriculture, Trinidad.
<i>Finland:</i>	Mr. H. Levonen, Horticultural Advisory Officer, Ministry of Agriculture.
<i>Germany:</i>	Dr. Werner Arnold, Director of Mushroom Research, Dieskau. Miss G. Fritzsche { Max-Planck-Institute of Plant Mr. W. Huhnke { Breeding, Hamburg. Professor Dr. E. L. Nuernbergh, Botanic Laboratory, Hamburg. Mr. H. J. Tschierpe, Technical University, Berlin.
<i>Holland:</i>	Dr. K. Verkerk, Laboratorium voor Tuinbouwplantenteelt, Agricultural University, Wageningen. Ir. W. van Soest, Director, Proefstation voor de Groenten en Fruitteelt onder Glas, Naaldwijk. Ir. J. M. Jacobs. ————— do. ————— Party of Dutch growers from The Hague.
<i>India:</i>	Mr. N. Srivastava, Plant Pathologist, Ministry of Agriculture, New Delhi.
<i>Israel:</i>	Miss Avigdori Hadasa, Assistant to Director of Vegetable Growing, Ministry of Agriculture.
<i>Kenya:</i>	Dr. F. L. Sheffield, E.A.A.F.R.O., Kikuyu.
<i>Malaya:</i>	Mr. C. C. Akhurst, Rubber Research Institute. Mr. J. Dore, Department of Agriculture.
<i>New Zealand:</i>	Mr. K. J. McNaught, Horticultural Liaison Officer, Soil Research Station, Hamilton. Mr. P. Blomfield, New Zealand representative of Potash Ltd.
<i>Nigeria:</i>	Dr. J. M. Waterston, Director of Federal Agricultural Research.
<i>South Africa:</i>	Mr. M. Chitters, Medical Centre, Johannesburg.
<i>Spain:</i>	Mr. Leopoldo Massieu, Las Palmas. Mr. V. Nif, Valencia.
<i>Thailand:</i>	Mr. Kahn Jalavicharana, Chief of Plant Industry Division of Thai Ministry of Agriculture.
<i>Uganda:</i>	Dr. E. M. Chenery, Department of Agriculture, Kampala. Mr. P. H. Le Mare, Cotton Research Station, Namulonge.

<i>U.S.A:</i>	Dr. J. G. Bald, Department of Plant Pathology, University of California, Los Angeles.
<i>Yugoslavia:</i>	Mr. Hamid Pasic, Director of Hydrometeorological Institute, Sarajevo. Mr. Siskov, Entomologist.

Acknowledgments

The Director would like to acknowledge the warm support of the Governing Body during a year when the continued development of the Institute posed many problems. He is also greatly indebted to the staff of the Agricultural Research Council for their sympathetic interest and encouragement, and for their help in numerous ways. Finally, he would like to record his grateful thanks to the Institute's staff, of all grades, whose loyalty and hard work, often under difficulties, made it possible to report a year of genuine progress.

SUMMARY OF RESEARCH

The research programme was continued along very much the same lines as in the previous year. The range of crops studied, however, was extended by the Plant Breeder's work on lettuce, and by the Crop Protection Department's investigations of the control of chrysanthemum mildew. Plans were also made for a long-term experiment on the nutrition of carnation, a crop which had hitherto been grown only for observation, although the pathologists have investigated the wilt diseases in the laboratory.

The physiological study of the growth of the tomato has been continued, and associated practical questions of plant spacing and pruning have been investigated in a preliminary experiment. Pursuing the growth analysis work, the effect of planting date on the development of the tomato is being studied in an experiment which was started in the autumn and will be fully reported later.

The chemists have begun to investigate certain aspects of the liquid feeding of tomatoes, with particular reference to the potash/nitrogen ratio in the nutrient solution. Magnesium deficiency of the tomato has also been studied.

In the field of pests and diseases, the most important new development, apart from that mentioned above, was the Entomology Department's work on the Glasshouse White Fly and its parasite, *Encarsia formosa*.

Mushroom research was still somewhat handicapped by lack of full facilities which, as reported in an earlier section, were being provided towards the end of the year, but considerable improvements were made to the old Cheshunt growing shed and this made possible a useful year's work.

PLANT PHYSIOLOGY

The Plant Physiology Department, under Dr. E. R. Leonard, continued its work on the tomato, with particular attention to the variety "Potentate", the one most widely grown. The principal stages in the construction and equipment of a special experimental glasshouse for physiological work were completed. Meanwhile, work continued in the present laboratories, in the trial glasshouses and in a temporary field laboratory erected in one of the glasshouses in 1956.

Using this last laboratory and instruments in the adjacent glasshouse, observations were continued on temperature and radiation in connection with evapo-transpiration studies of tomato plants in pots containing tensiometers. In the same glasshouse, soil moisture tension variability and trends in time at different depths and distances from tomato plants were again studied. Ebermeyer-type lysimeters were also installed to make a preliminary assessment of their behaviour.

Tomato pruning and spacing

The basic study of the growth of the tomato carried out over three years at Cheshunt and at the Institute have led to an investigation of more practical aspects of tomato cultivation. In the previous year it was shown that if all the side shoots below the first truss, on widely-spaced plants of "Potentate", were retained, the average yield per plant was nearly three times that obtained from single-stemmed plants. In 1957 an experiment on the interaction of pruning and spacing was laid down in two adjacent glasshouses of a vinery-type block with the object of determining whether this constituted an increase in yield per unit area of glasshouse space, the factor which is of most concern to the grower. Single-stemmed plants, i.e., those with all the side shoots removed, were compared with multi-stemmed plants, i.e., those in which all the side shoots below the first truss were allowed to develop, in N-S rows at three different spacings between rows. A summary of the results is given in a paper by Dr. Cooper published in this report. Dr. Cooper has also undertaken a critical review of the literature on the spacing of tomato plants in commercial cultivation, and as this must be of considerable practical interest to growers besides being relevant to the Plant Physiology Department's growth studies, it, too, is published in this report.

The literature review shows that there is no clear-cut answer to the question as to how far apart tomatoes should be planted if maximum yields are to be obtained, and the yield results from the experiment reported do not support or disprove the view, found in much of the literature, that the yield of a given area increases as the planting density increases. Although the results showed that single-stemmed plants at the closest spacing tested (21,780 plants to the acre) gave the greatest weight of crop per unit area of glasshouse (and, incidentally, gave fruit of as good a quality as that obtained with any of the other treatments tested), the increase in yield obtained by increasing the planting density above 14,520 plants per acre was not significant statistically.

In reviewing the results on spacing experiments with tomatoes reported in the literature Dr. Cooper points out that the inconsistency in these results may be due to the fact that no one appears to have studied possible interactions between planting density and watering and manuring. It is thus still open to question whether those workers who reported increased yields per unit area with increased planting density were applying adequate fertilizer and/or water to support the higher yield at the greater density, and whether those who failed to obtain increased yields were not doing so. There is thus room for much further study of the spacing question, and the effect of spacing on early cropping and the economic aspects of planting at closer spacing need particular consideration.

CHEMISTRY

The Chemistry Department, under Dr. G. W. Winsor, covered a very wide field of work, and in addition to continuing most of the investigations in progress during the previous year, carried out a range of experiments on the nutrition of the tomato with particular reference to the concentration of nutrients and the potash/nitrogen ratio in liquid feeds and to the role of magnesium. The study of the role of boron in the nutrition of tomato plants was dropped, and the important work on the effects of soluble salts in glasshouse soils, as indicated by the conventional *pC* test, has been left temporarily in abeyance but will be taken up again when other work has been rounded off.

Composition of the tomato fruit

The chemical composition of tomato fruit has been studied more extensively along the lines previously pursued. The investigation is being undertaken in relation to variety and state of ripeness of the fruit, and has particular reference to problems of fruit quality and ripening disorders.

Composition in relation to grade, as judged by external characteristics more or less in accordance with the commercially accepted standards, has been specially studied. It was found that composition was not markedly affected by normal differences in the shape of the fruit, although multi-locular fruit of highly irregular shape tended to have a lower acidity, and hence a higher sugar/acid ratio, presumably because of their higher proportion of fruit wall, which has been shown to have a lower acidity than that of the internal parts of the fruit. It was confirmed that "blotchy" and "waxy" fruit had a lower acidity and less sugars and total solids than normal fruit. Curiously enough, fruit with a deep green colour around the calyx showed very high values for sugars, total solids and acidity; such fruit would not normally be classed as top grade, but analytically it appears to be of the highest quality.

The symptoms associated with abnormal ripening in the tomato are, for the most part, observed in the fruit walls, so it becomes of interest to know whether the observed differences in the composition of whole "blotchy" or "waxy" fruit are due solely to differences in the composition of the fruit walls or whether the inner parts of the fruit are affected as well. The analyses showed that the free juices of the tomato are markedly more acid than sap expressed from the outer fruit walls, but contain less sugars and consequently have a much higher ratio of acid to sugar. Statistical treatment of the results from numerous samples showed that the composition of the free juices was related to that of sap expressed from the fruit walls, and this finding, taken in conjunction with the analytical results for fruit displaying various types of irregular colouring, led to the conclusion that although ripening disorders are for the most part made evident by their effects on the outer fruit walls, the associated chemical changes are not confined to the walls but are also found in the inner portions of the fruit as well.

Further study was made of the ripening processes in tomato fruit, mainly with the object of establishing the trend of changes in acidity during the ripening of the fruit walls for which inconsistent results were obtained in the previous year. It was found that although the acidity in the walls increased from the green stage to the first appearance of yellow pigmentation, there was no consistent trend as ripening proceeded further. The results for acidity of the fruit walls were in marked contrast to those for juices obtained from the inner portions of the fruit; with the latter, the acidity was found to be high initially and to decrease markedly as the fruit ripened. The sugar content of the free juices increased steadily during ripening.

As a result of this work on the changes in the composition of tomato fruit during ripening, most of the trends are now clearly established, namely those for total solids, sugars and acidity in the sap from whole fruit and in the free juices, as well as those for total solids and sugars in the sap from the fruit walls. It is only the acidity of the fruit walls that presents a confusing picture. This is in contrast to the consistent differences in acidity found previously for the various coloured areas of the walls of "blotchy" fruit. As the authors of the paper reporting these results point out, the influence of physical factors, such as light and temperature, on the acidity of fruit walls and of whole fruit merits further attention.

Parallel studies were carried out to determine the effect of removing the leaves from tomato plants on the composition of the fruit. These were undertaken with the object of finding the possible causes of the observed differences in fruit composition, as it seems likely that they will be determined directly or indirectly by physical factors, such as light and temperature, and also by the balance of fruit and foliage present. Since sugars and organic acids are, for the most part, produced in the leaves and are thence transported to the developing fruits, the composition of the fruit may be expected to vary with leaf area, as has been shown for a number of crops. In three series of experiments removal of leaves greatly reduced the sugar and dry matter content of the

fruit, and reduced the concentration of sugars and total solids in the expressed sap. The acidity of the expressed juices was not markedly affected, however, and conflicting results were obtained from the three sets of trials.

As has been shown during the course of this work, the concentration of soluble solids in the expressed sap of tomato fruit varies considerably in relation to fruit quality and variety. In order to examine fruit samples more quickly and to facilitate the testing of larger numbers of fruit, the use of relatively rapid physical methods for assessing the concentration of soluble materials in the sap have been considered. Such methods are usually based on the density of solutions, but the most promising results have been obtained by measurement of the refractive index. This method has been widely used for rapid analysis and quality control with other crops. Preliminary trials involving the measurement of refractive index in relation to the total dissolved solids in the sap of several hundred samples of tomato fruit, using a simple hand refractometer, showed a very high and significant correlation between the readings obtained with the instrument and the actual percentage of total solids as determined by the ordinary oven-drying method. The use of a refractometer for rapidly determining the soluble solids in tomato fruit thus shows considerable promise, and further trials are to be made with a more sensitive instrument.

Dr. Davies continued his investigation of the organic constituents of tomato fruit by means of chromatographic methods. Particular attention was paid to the quantitative determination of the individual free sugars, and excellent separation of glucose and fructose was eventually obtained. These sugars seem to make up the bulk of the sugars present in the fruit, and their combined amounts determined chromatographically agreed very closely with the amount of reducing sugars estimated by the normal volumetric method. Traces of a sugar indistinguishable chromatographically from sucrose have been found in one or two samples of ripe tomato fruit, but, in general, sucrose appears to be either about or below the threshold of detection.

Soil analysis and its relation to tomato yields

The analysis of soil and tissue samples taken during the course of the calibration of the two blocks of trial glasshouses, B1-4 and C1-4 (see page 12 of report for 1956) was continued, and a paper summarizing the analytical results for soil samples taken during 1955 and discussing their relation to crop yields is published in this Report. The corresponding results for 1954 have been previously published. As has been mentioned, the soil in these two blocks of glasshouses was deliberately kept at a low level of fertility in order not to prejudice the use of the houses for future experiments on soil nutrition. The analytical results showed that the levels of available phosphate and potash in the soil during both 1954 and 1955 were below the requirements of the crop. Analyses of leaf samples taken during 1955 not only confirmed the low availability of potash, but also showed that the amounts of nitrogen available to the plants were inadequate. Thus three major plant nutrients were insufficient for optimum growth of the plants, and it is perhaps not surprising, therefore, that there was no consistent correlation between crop yields and the levels of any one nutrient. In fact, the correlation results as a whole presented a very confusing picture, and it is difficult to draw any useful conclusions from them. Considerable caution is thus required in assessing the analytical results obtained.

Urea-formaldehyde compounds as nitrogenous fertilizers

The work on urea-formaldehyde compounds, which was started in 1950, is being rounded off in favour of work on other subjects which are becoming of more pressing importance. A concluding report is published herewith. The report gives an account of experiments on the growth of tomato plants in potting mixtures containing various urea-formaldehyde compounds, and of parallel studies in the laboratory on the rate of mineralization of the nitrogen in these compounds.

In the previous year a methylene urea compound, designated as UFT. 5, had shown promise, and in the 1957 trial now reported, this compound and others of the same type, together with a methylene ether compound, were tested in comparison with the conventional hoof and horn. The methylene urea compound, UFT. 5, was again promising, and with tomato plants grown in pots gave a crop yield which was almost identical with that obtained with hoof and horn. This was despite the fact that the compound was supplied all at one time in the potting mixture, whereas the hoof and horn was supplied in the more usual way, partly in the potting mixture and partly in top dressings applied throughout the period of growth. With potted plants it would of course be a very great convenience to be able to put the whole of the manurial dressings in the compost at the time of potting up. The slow-acting character of the urea-formaldehyde compounds, and particularly of UFT. 5, was well brought out by the poor yield obtained when hoof and horn was applied in the same way as with these compounds, namely, entirely in the potting mixture.

The methylene ether type of compound also showed promise, and it is clear that with this and some of the methylene urea types there is a range of compounds which offer much scope for the development of slow-acting nitrogenous fertilizers which would be of considerable value in glasshouse practice. Unfortunately, this work cannot be pursued at the Institute, for the reason already given.

The paper includes analytical data for the urea-formaldehyde compounds and the results of laboratory studies on their rate of decomposition in soil. Some caution must be exercised, however, in using this information as a guide to the value of the compounds as slow-acting fertilizers in plant-growth trials. Despite this proviso, it is quite evident that some urea-formaldehyde compounds possess the valuable property of releasing inorganic nitrogen slowly and fairly steadily, and are therefore greatly superior to natural organic compounds such as hoof and horn, which is usually regarded as the best slow-acting nitrogenous material for potting mixtures and similar uses.

The paper concludes with a brief note on certain properties of some methylene ether products which hitherto have attracted little or no attention as possible slow-acting nitrogenous fertilisers.

Nutrition of the tomato; some problems of liquid feeding

The study of the nutrition of the tomato plant, a subject that featured in the programme of the Experimental and Research Station at Cheshunt over many years, has been resumed, and with the better facilities now available at the Institute it has been possible to plan the work on a more satisfactory scale. Although numerous investigations have been carried out in this field in the past, there is a good deal still to be learned about the nutritional requirements of the tomato. Of topical interest are some of the problems that arise with liquid feeding, a method of feeding now widely adopted, particularly where automatic irrigation systems are used. The saving of labour, and the better control of feeding, that automatic irrigation makes possible are of considerable importance to the grower, and the feeding aspect provides a very useful field for research. A series of experiments on this subject was started in 1957.

In one experiment, the object was to investigate the effects of various concentrations of nutrient on cropping and fruit quality, with accompanying studies of the resulting nutrient concentration both in the plants and in the soil. In this experiment the potash/nitrogen ratio in the liquid feed was kept constant at 1.75, but four different concentrations of solution, ranging from 75 to 300 parts per million of nitrogen, were tested in a replicated and randomized fashion. The first year's results from this trial are reported in detail in a separate paper in this Report. The analyses of soil samples showed interesting trends which although not altogether unexpected will need confirmation in subsequent years before being accepted as definite. The analyses of leaf samples showed that the levels of nitrogen, phosphate and potash were fully adequate with all

nutrient treatments, and, in fact, were very little different for any of the treatments. The variety chosen for the experiment did not yield well, and there was a significant reduction in crop from the more concentrated feeds. By contrast, the proportion of good quality fruit increased with increasing nutrient concentration. Although only the most tentative conclusions can be drawn from one year's results the observed effects on cropping and fruit quality, taken in conjunction with the soil and leaf analyses and the appearance of the plants, appear to be of a physical rather than of a nutritional nature, related to the concentrations of soluble salts present in the soil.

In a second experiment the effect of varying the potash/nitrogen ratio on growth and cropping was studied, the opportunity being taken to explore the use of trickle irrigation equipment in nutritional trials. Experience during the first year showed that such equipment could be used quite satisfactorily in replicated and randomized experiments with numerous small plots. The crop results from the experiment showed that the yield of good quality fruit was increased as the potash/nitrogen ratio in the liquid feed was increased, but the proportion of uniformly coloured fruit was relatively low and there were marked differences in the growth of the plants in various parts of the house, apparently related to light intensity, which affected growth and cropping. An interesting finding from the accompanying soil analyses was that at the end of the season the potash supplied in the nutrient solutions remained localized in the vicinity of the trickle nozzles, whereas the highest concentrations of total soluble salts were found mid-way between nozzles. Again, these conclusions from the first year's results must be accepted as only very tentative.

Magnesium deficiency in the tomato

Yellowing of the foliage caused by magnesium deficiency is very commonly seen in glasshouse tomatoes, although it is well known that it can be quite readily corrected by spraying the plants with a solution of magnesium sulphate. Nevertheless, spraying does not seem to be a popular treatment, and it is not certain that it is worth while. Control of the deficiency by soil applications of a magnesium fertilizer seems to require relatively large quantities to be effective, and might lead to difficulties arising from excess soluble salts in the soil.

The subject is being investigated in a series of glasshouse experiments the first of which was carried out in 1957. In this experiment two varieties of tomato, "Potentate" and "Immuna", were grown with a medium and high level of potash in the soil, and the effects of soil applications or foliar sprays of magnesium were determined. The different levels of potash were included because there is reason to believe that the ratio of potash to magnesium in the soil may influence the occurrence of magnesium deficiency symptoms. The variety "Immuna" is a Swedish F₁ hybrid which is said to be markedly susceptible to magnesium deficiency.

Definite symptoms of magnesium deficiency appeared in both varieties, although more markedly in "Immuna"; with this variety the symptoms were quite marked even where magnesium sulphate was applied to the soil, but they were very largely controlled by spraying magnesium sulphate on the leaves. "Potentate" responded more readily to the soil treatment and almost completely to the foliar sprays.

The crop yields were recorded and the fruit was graded into categories according to shape and uniformity of colouration. The soil in the various experimental plots was analysed at the beginning of the experiment and at two subsequent dates during the course of the crop. Leaf samples taken in May and June were also analysed.

There were no significant differences between the crop yields under the various treatments, but "Immuna" gave a higher yield than "Potentate" in nearly all plots and the difference in yield of these two varieties was highly significant statistically. As regards quality of fruit, there was some indication of an increase in top quality fruit where magnesium was applied at the higher level

of potash, but by far the most marked difference was again between varieties, "Immuna" giving a much larger proportion of top quality fruit and less irregularly coloured fruit than "Potentate". The most striking feature of these results is that crop yields were largely unaffected by the marked degree of chlorosis in the foliage, and there was no suggestion of any reduction in fruit quality.

The experiment showed clearly that foliar sprays containing magnesium are more effective than soil treatments in maintaining the normal green colour of the leaves. This result was not entirely unexpected, of course, but the curious thing is that the leaf analyses showed that at the second date of sampling (in June) the uptake of magnesium by the leaves was very much higher where magnesium was applied to the soil than where it was applied as a spray. Analysis of the soil samples showed that there was a considerable increase in the amount of available magnesium in the soil where magnesium sulphate had been applied to the soil.

It must be emphasized that these results are of a preliminary nature only, and the experiment will be run for another year or two to see whether they can be confirmed.

Factors of the compost and casing layer in relation to fruiting of the cultivated mushroom

Further work bearing on the function of the casing layer in mushroom cultivation has been carried out, and it now seems clear that the usually held belief that the casing layer stimulates the mushroom to fruit because it is a very much poorer nutrient medium compared with the compost must be abandoned. In a large scale bed experiment confirmatory evidence was obtained that the addition of compost, in a dried and ground condition, to the casing layer increased the yield of mushrooms, and there was further evidence that this is likely to be a nutritional effect. Recent work in the United States lends support to this finding. The practical possibilities of increasing yields by the addition of compost to the casing layer are being explored.

Following on the previous year's work in which marked effects on fruiting were obtained when salts were added to the casing layer, special attention has been directed to the soluble salt content not only of the casing layer but also of the compost. Samples of compost obtained from a number of commercial farms were found to give very low pC values and to contain amounts of soluble salts ranging, generally, from about 5% to 8%. The low pC values indicated the presence of more highly ionised salts in addition to any calcium sulphate that may have been present. By contrast, the casing layer, whether composed of soil or a peat-chalk mixture, normally has a much lower salt content, usually less than 1%. In a pot experiment with spawned and unspawned compost cased with soil, it was found that the soluble salt content of the compost increased considerably as decomposition of the compost proceeded.

It seems, therefore, that the medium in which the mushroom for the most part grows and from which it obtains most of its nutrients is one of relatively high soluble salt content and must presumably have a high moisture stress. The moisture stress in the casing layer, on the other hand, must be much lower than in the compost, and most of the moisture present in the normal casing layer is probably readily available to the mycelium. Whether the change from a medium of high salt content and high moisture stress to one of relatively low moisture stress has any influence on the initiation of fruiting has yet to be established, but it is an interesting possibility that will be worth exploring further.

Further evidence was obtained that a movement of salts can take place from the compost to the casing layer, but this was found to be independent of the presence of mushroom mycelium. It would appear, therefore, that the movement of salts is due to physical processes, such as evaporation at the surface of the casing layer leading to the upward movement of moisture containing

dissolved salts, probably combined with some diffusion of salts from the compost into the casing layer. It is not yet possible to decide, however, whether the rise in the concentration of salts in the casing layer is of any significance as far as cropping is concerned. This is another matter that will be worth investigating further.

PLANT BREEDING

The Plant Breeder, Mr. L. A. Darby, has initiated well-planned programmes of work for the improvement of tomato, cucumber and lettuce, and the main objectives are outlined in his report.

With the *tomato* an attempt is to be made to reduce the excessive vegetative vigour of F_1 hybrids, which has hitherto limited their acceptance by the industry, by incorporating the compact habit of the "Baby Lea" variety. Attention is also being paid to fruit size, shape and colour, with the object of improving fruit quality. It is hoped to control fruit size and shape by increasing the number of flowers on the truss. The investigation of fruit colour has particular reference to the occurrence of non-uniformly coloured fruit, usually described as "blotchy ripening" or "green back", which reduces the value of some varieties, especially the one most widely grown ("Potentate"), and leads to considerable financial loss. It is known that there are many genetic factors which affect the production of pigments and modify their quality, quantity and distribution in the fruit, and these factors are being introduced in lines of "Potentate" and "Ailsa Craig" to compare their effects in different genetic backgrounds. In this way it is hoped to produce new varieties which, while still giving red fruits, might be more stable and therefore less subject to abnormal ripening.

With the *cucumber*, F_1 hybrids are also being studied in the hope of improving yield and fruit quality and of obtaining a more uniform crop and more constant production. In this project special attention is being paid to the number and weight of fruit in the early and total crops, and to fruit quality in terms of colour, spines and neck-length. A further programme has been started to improve the fruit quality of the two commonly grown varieties, "Butcher's Disease Resister" and "Telegraph", by stabilizing the handle at a short attractive length in the former and by increasing the spinyiness of the latter. An attempt is also being made to select or produce male-sterile types, possibly triploids, the fruit of which would not set seed if bees should get into the glasshouse. Not only does seed-setting reduce the value of the fruit but it also checks the growth of the plants.

The work on *lettuce* is confined to winter-forcing varieties grown under heated glass. From enquiries carried out in Lancashire, the main area of production, it seems there is a demand for a variety which will heart as well as existing varieties, but which has a lighter green colour. An attempt is being made to achieve this both along orthodox breeding lines and by exploiting mutations induced by atomic radiation.

PLANT PATHOLOGY

The Plant Pathology Department, under Mr. P. H. Williams, continued its work on *Didymella* Stem Rot of the tomato, powdery mildew of the cucumber, wilt diseases of the carnation, and mushroom diseases. Certain experiments on the chemotherapeutic control of tobacco mosaic virus in the tomato were also carried out.

Didymella Stem Rot of the tomato

The work on this important disease was considerably handicapped by the lack of a special research glasshouse which was not ready for experimental use until towards the end of the year. To avoid any risk of the disease spreading to the main part of the Institute's nursery it will be necessary to take very strict precautions, and for this reason it is proposed to confine the investigations to certain compartments in the research glasshouse.

Early in the year three officers of the National Agricultural Advisory Service reported a very interesting finding that the hormone weed-killer 2,4,6-T applied to tomato plants increased their susceptibility to *Didymella*. It seemed that this might be of considerable value in research on the disease by speeding up investigations on the viability of the fungus in soil. Small-scale pot experiments were therefore carried out to test the effect of 2,4,6-T on the infection of tomato plants by *D.lycopersici*. These experiments did not suggest that infection was increased by the application of the hormone, so the results previously reported have not been confirmed at the Institute. As the experiments were on a relatively small scale, however, further work is obviously desirable on this interesting point.

In another pot experiment it was found that the fungus, *Didymella lycopersici*, infecting the stems of diseased tomato plants, showed no great tendency to pass into the roots. Once again the experiment was on a small scale, but if this finding can be confirmed it is of some practical importance as suggesting that there is little risk of any considerable amount of infective material being left in the soil when a diseased plant is removed.

Further work was done on the apparent antagonism of certain soil organisms to the development of *Didymella lycopersici* in unsterilized soil. Previous work suggested that the antagonism was probably not due to a competition for nutrients, but was more likely to be an antibiotic effect. As a preliminary to tests with antagonistic organisms, isolations were made of a wide variety of organisms from soil from one of the glasshouses at the Institute and tested for their inhibitory effect on *Didymella lycopersici* in the laboratory. Not unexpectedly, the degree of inhibition was found to vary considerably, and certain of the organisms showing the inhibitory effect are being grown in soil in order to test their ability to render it unsuitable for colonization by *D. lycopersici*.

Cucumber Mildew

The search for resistance to cucumber mildew within the family Cucurbitaceae was continued by growing plants of those species which had appeared resistant or immune in the previous year in the glasshouse under normal cucumber growing conditions. Only *Ecballium elaterium* and two species of *Luffa* proved completely free of mildew. It does not appear, however, that the immune species are likely to cross readily with cucumber to give resistant varieties of the latter, so this line of work is being dropped.

The study of other hosts for cucumber mildew was extended, but it became evident that successful cross-inoculations of mildew on to cucumber were dependent either on the condition of the host or on environmental factors. Infections were obtained more readily in the winter months, suggesting a possible effect of light on the host. To investigate this a technique was developed for illuminating plants for a specified time, and experiments are proceeding with the apparatus devised.

No progress can be reported in determining the correct botanical identification of the cucumber mildew fungus. Inoculation experiments with perithecia (the perfect stage of mildew fungi) found on plants of sowthistle and creeping buttercup growing in the glasshouse, which it was hoped would throw light on this question, proved abortive.

Petal Blight of chrysanthemums (*Itersonilia perplexans*)

During the autumn the fungus causing Petal Blight was isolated from the flowers of chrysanthemums growing on a local nursery. The fungus was identified as *Itersonilia perplexans*, and was shown to produce flower scorch when inoculated on flowers of chrysanthemum in a moist chamber. It is hoped to study the conditions necessary for the appearance of the disease, as well

as possible methods of control. The host range of the fungus is also of interest since it has been recorded on several flower crops, such as chrysanthemum, dahlia and sunflower, and also on parsnip; on the latter it is one of the causes of Parsnip Canker.

Carnation Wilt Diseases

A number of species of the family Caryophyllaceae have been tested as possible alternate hosts for the fungi commonly isolated from diseased carnations, including those fungi known to cause wilt diseases. No definite symptoms appeared on the seedlings tested, but it proved possible to re-isolate from one of them, *Melandrium album* (White Campion), two of the fungi (*Fusarium roseum* and *Verticillium cinerescens*) used for inoculation. *M. album* is a common weed of arable land, and as it can apparently act as a carrier for two of the fungi which attack carnations it may be the means whereby these fungi survive in field soil and are carried over into carnations.

Pursuing the study of Slow Wilt, the bacterium associated with the disease, which has been regarded as a strain of *Erwinia chrysanthemi*, was inoculated into young carnation plants to test its pathogenicity and also into two young chrysanthemum plants. Typical wilt symptoms developed on the carnation plants in 5–7 weeks, but no external symptoms developed on the chrysanthemum plants in three months. The bacterium was re-isolated from both sets of plants. It is very possible that other strains of the carnation pathogen would vary in their ability to infect and produce symptoms in chrysanthemums.

The occurrence of disease in the Institute's carnation houses has been studied since they were planted in the spring of 1955 for the first time, and just before the crop was pulled out at the end of 1957 a survey was made of the gaps left by the removal of diseased plants from time to time. Although in several beds a large percentage of plants had been removed, the scatter of diseased plants was such that no very obvious patches appeared in the crop, the plants adjacent to those removed being easily trained in to fill the gaps. Isolations from a selection of the diseased plants during the three-year period of growth showed that in nearly all cases infection was due to *Fusarium roseum*. A few isolations of the wilt fungus *Fusarium oxysporum* were also made, but *Verticillium cinerescens* was never isolated. Certain differences were noted in the incidence of disease in the varieties grown and in its occurrence in various parts of the houses.

Preliminary experiments with gibberellic acid suggested that it may be effective in increasing shoot length in carnations. This might be of some value in obtaining cuttings, possibly freer of wilt diseases, but a good deal more work will be needed to test this thoroughly.

Mushroom disorders

The study of those ill-defined mushroom disorders of the "La France" type, which have caused so much concern to growers in recent years, received considerable impetus as a result of severe outbreaks on commercial farms during the autumn of 1957. A variety of names were used to describe the troubles experienced, the most popular being "Brown" disease and "Watery Stipe". In many cases, however, the outbreaks showed a strong resemblance to those previously ascribed to La France disease. As the cause of these disorders is at present unknown, they can only be referred to by their symptoms, but these vary so much that they form a questionable basis for distinguishing the disorders. A comparison of the symptoms observed in the 1957 outbreaks with those recorded for La France disease, Mummy disease, and Damping-off shows considerable overlapping, and almost every symptom is common to more than one disease already described. The trouble is, of course, that the mushroom, a lowly organism, shows so little specialisation in its structure that it can only react to disease in a limited number of ways. The confusion of symptoms makes the study of these disorders particularly difficult.

A cropping experiment was carried out to see whether any of the disorders could be transmitted through the mycelium. The spawns used were made from mycelial and tissue cultures of mushrooms from abnormal crops on commercial farms. Several of the spawns gave very low yields, but no marked deformities were observed in the mushrooms produced. The great reduction in yield was one of the most serious aspects of the outbreaks on commercial farms in 1957, but it was usually accompanied by various types of deformity in the mushrooms produced. The results from the cropping experiment very largely confirmed those obtained with pot experiments in the previous year.

Further studies were made in the laboratory of the growth on agar media of mushroom cultures isolated from abnormal crops on commercial farms. There were again very noticeable differences in the appearance of several of the cultures, and, for the most part, they were quite different from cultures obtained from normal crops and grew more slowly.

A preliminary examination of abnormal mushroom tissue under the microscope has been made, and it appears that in the waterlogged areas which give rise to the "watery stipe" symptom the tissues are disorganised and the cell walls broken down, the areas becoming colonised by bacteria.

Virus diseases

Staff and facilities for work on virus diseases are at present very limited, but a number of experiments in which the control of tobacco mosaic virus of tomatoes was attempted by chemical means were carried out. These experiments included the treatment of infected seed with 2-chlorophenoxyacetic acid, where some suggestion was obtained that the treatment might be effective in freeing seed of virus, and the study of the effect of various phenoxy acids on the rate of spread of tomato mosaic. In the latter case there was an indication that two of the substances tested might delay the spread of infection, at least initially, but the effect was not sufficiently marked to be of commercial interest. The results of all the experiments were most inconclusive, however, and suggest that the chemotherapeutic approach to the control of tomato mosaic does not offer any great prospects of success.

ENTOMOLOGY

The staff of the Entomology Department, under Dr. N. W. Hussey, was increased by the appointment of an additional entomologist, principally to enable the Department to extend its work on mushroom pests. A particular subject chosen for study is the paedogenesis of Cecids affecting mushroom beds, but Phorids and Sciarids are also receiving attention.

The work on Red Spider Mite was continued, and the studies on the Glasshouse White Fly and its parasite have made good progress.

Glasshouse White Fly

From enquiries received at the Institute it is evident that there is still considerable interest in that common pest of glasshouse crops, the White Fly, and in means of controlling it. With specialised cropping under normal commercial conditions the pest should be readily controllable by insecticides if they are properly applied, but where mixed crops are grown there may be risks involved because of the different tolerances of the plants to chemicals. The chalcid wasp parasite, *Encarsia formosa*, is no longer being bred for general distribution, and it has become evident that before any steps are taken to re-introduce this method of control a good deal more must be learned about the efficiency of the parasite under various conditions. Recent work in Canada

suggests that temperature has an important effect on host/parasite balance, and it is clear there are many gaps in our knowledge of this and other subjects. The Entomology Department has therefore re-opened the investigation of Glasshouse White Fly and its control by biological means.

Among the subjects selected for study is the effect of temperature on the fecundity and rate of development of the White Fly, and preliminary results are given in this report. The effect of tomato variety on egg laying has also been investigated. In the course of rearing white flies for these and other studies a number of adults were found to be attacked by a parasitic fungus, but it seems unlikely that this would offer any scope for the development of another biological means of controlling the pest.

Special attention has been given to the problem of assessing white fly populations, and exploratory samplings have indicated a number of variables that must be taken into account in future work.

Some very interesting observations have been made on the puncturing of White Fly scales by the parasite, *Encarsia formosa*, and these provide additional information on the efficiency of the parasite as a means of controlling the pest.

Mushroom pests

The study of the insect fauna of light stable manure stacked in the open was continued for the remainder of the twelve months' period originally envisaged. A further eight species were bred out, making a total of 72 species identified altogether, to which must be added a number of catches which were not determined. Forty of the recorded species were Coleoptera, an order which has not so far been recorded as containing a mushroom pest, and a further sixteen were in the Sphaeroceridae, a family whose status is in dispute. Of the remainder of the fauna only the Sciaridae are of importance.

The taxonomic classification of the Sciarids has been specially studied, and a provisional key to the identification of female Sciarids associated with mushroom compost, with illustrations of the features on which identification is based, is published with this report.

Preliminary results have been obtained from the catches made with light traps in a growing house. The most noteworthy observation so far is that adult Cecid flies (*Heteropeza*) were trapped only in small numbers, and then mainly in the first four weeks of cropping, but by the end of cropping the beds had a heavy infestation of Cecid larvae.

The work on paedogenetic Cecids was continued and has been fully reported elsewhere (Hussey & Wyatt, *MGA Bulletin*, **100**, 1958, pp. 150-158). It appears that only four species infesting mushroom beds need be considered in this country, and of these *Heteropeza pygmaea* seems to be of most importance economically. Characters for distinguishing all these species have been described in the publication mentioned. Preliminary studies have been made of the effects of temperature on the rates of larval development, and experiments were also carried out to determine the lethal temperatures of two of the species in order to establish whether normal peak heating temperatures would kill the larvae which might be present in the compost. The effects of starvation on larval populations has also received a preliminary investigation. A study of the natural habitats of the Cecid species has been started and has revealed a number of interesting and unsuspected sites.

The work on Phorids has led to the discovery of an eelworm which is parasitic on the Worthing Phorid Fly, *Megaselia halterata*, and the life cycle of the eelworm has been studied. The activity

of the adult flies does not seem to be impaired by large eelworm populations in their bodies, but the reproductive system of the females seems to be affected and egg laying is reduced. The possibility of developing a biological method of controlling Phorids, using the parasitic eelworm, is being considered.

Red Spider Mite

The investigation of colour forms in Red Spider Mite has been rounded off, and the conclusion has been reached that there are two forms, reddish-brown and green, which should be regarded as sub-generically distinct. The implication of this work is that when testing acaricides the precaution must be taken to use only pure inbred lines.

Continuing the studies on the physiology of the insect, the effect of temperature on the rate of development of the green form was found to be exactly the same as that for the reddish-brown form, the results for which have already been published. The effect of humidity in relation to temperature on the number of eggs produced by both the green and reddish-brown forms has also been investigated. It was found that the fecundity of both forms is adversely affected by high humidity, and there was an indication that for any given combination of temperature and humidity the green form tends to reproduce more rapidly than the red, though this will require confirmation. Further work showed that the development of the two-colour forms is little affected by long periods in a saturated atmosphere, although the green forms seemed slightly more resistant to these conditions.

Early in the year observations were made to obtain information on the first stages in the infestation of a cucumber crop by the mite. The observations, recorded later in this report, are of interest in showing the rapid way in which an infestation may build up from a very small primary attack.

CROP PROTECTION

The Crop Protection Department under Mr. W. H. Read, has branched out into new fields and has undertaken work on the control of mildew on chrysanthemums and aphids on lettuce. The residues from diazinon used for the control of Red Spider Mite on cucumbers have also been determined.

Control of chrysanthemum mildew

An experiment with four varieties of chrysanthemum in which salicylanilide, thiram and the active principle of "Karathane", either alone or mixed with a petroleum emulsion, were tested, with appropriate controls, showed that the best control of chrysanthemum mildew was obtained with salicylanilide or "Karathane" in combination with petroleum. It appeared that the superior control may have been due to the longer period of protection given by the addition of petroleum to the fungicides. It is necessary to issue the warning, however, that there may be pronounced varietal differences in the response obtained, and climatic and cultural conditions may affect susceptibility to damage. The most satisfactory concentrations of fungicide and petroleum can therefore only be determined by a large number of trials on a wide range of chrysanthemum varieties. Hence growers should proceed cautiously in applying the results of the experiment reported.

Determination of diazinon residues on cucumbers

Although diazinon is known to be considerably less toxic than certain other related organo-phosphorus compounds, there is at present no information on the residues likely to result from

its use on food crops. It is therefore officially recommended that there should be a minimum interval of fourteen days between the last application and the harvesting of the crop. This is not practicable with cucumbers, where diazinon would be valuable for the control of Red Spider Mite, and it is therefore important to determine the residues likely to arise from the normal use of diazinon on cucumbers to ensure there will be no risk to consumers if the interval between application and harvesting is greatly reduced. A similar question arises with the use of diazinon for the control of flies in mushroom houses.

The determination of diazinon residues on cucumbers has been investigated, and this involved first of all tests to see whether the two recognised methods for the laboratory estimation of diazinon could be applied to cucumbers. One method proved satisfactory, and it was used to determine residues resulting from the application of diazinon, in aerosol form, to a cucumber crop. Fruits for testing were picked one and three days after application, and again one day after a second application. In all experiments the residues found were so low that there appear to be no risks to the consumer from the use of diazinon under such conditions.

Control of aphids with fluoracetamide

Experiments have been carried out with fluoracetamide, used both as a fumigant and as a systemic insecticide, for the control of aphids. Lettuces were used as test plants because of their convenience, but it must be emphasized that fluoracetamide is not to be recommended for commercial use on lettuce as it is a highly poisonous compound.

Fluoracetamide is slightly volatile, and this makes it possible to consider its use in the vapour form. Tests showed that in this form good control of aphids was obtained at certain concentrations and temperatures, but in some cases damage to the plants resulted.

Used systemically by watering solutions on to plants in pots a good kill of aphids was obtained after three or four days with the three concentrations tested at a high growing temperature, but phytotoxic effects were shown. No phytotoxicity resulted at a lower temperature and at high humidity, but the highest concentration of fluoracetamide used failed to control the aphids.

Red Spider Mite investigations

Work on Red Spider Mite has been largely confined to developing a technique for the precise determination of the potency of chemicals towards active stages of the mite. For tests on cucumber a problem that has not yet been solved is the keeping of plants free of mildew by means that will not interfere with the acaricidal tests.

II. PLANT PHYSIOLOGY

1. A COMPARISON OF THE YIELDS FROM SINGLE-STEMMED AND MULTI-STEMMED TOMATO PLANTS AT THREE PLANTING DENSITIES

by

A. J. COOPER

It was shown from observations carried out in 1956 (1) that, using widely-spaced plants of the "Potentate" variety of tomato, retention of all the axillary shoots below the first inflorescence on the main stem increased the yield *per plant* nearly three-fold relative to single-stemmed plants. A trial was laid down in two adjacent sections of a vinery-type block of glasshouses to determine whether this constituted an increase in yield *per unit area* of glasshouse space.

Technique

It has been shown by Sheard (unpublished data) that the closer tomato plants are spaced within the row the greater the yield per unit area of glasshouse where conditions are such that competition between the rows themselves is slight or non-existent. On the basis of this work the spacing of the plants within the row for the 1957 trial was fixed at 1 ft. for the single-stemmed plants, and at 4 ft. for the multi-stemmed plants, i.e., the closest practical within-row spacing that is possible under commercial conditions.

Single (*not* double) rows were planted in a north-south direction to test the effect of three between-row spacings, namely, 2 ft., 3 ft., and 4 ft., corresponding to 21,780, 14,520 and 10,890 plants per acre respectively for the single-stemmed plants, and 5,445, 3,630 and 2,723 plants per acre for the multi-stemmed plants. The layout is shown in Figure 1 where the experimental plants in each treatment plot are shown connected by continuous lines. Guard plants and guard rows were arranged so that all edge experimental plants had the same spacing on both sides.

An attempt was made to ensure that soil moisture and soil nutrients were supplied in excess of requirements to ensure that the effect, if any, of between-row spacing would be one of aerial competition and not soil competition. Water and fertilisers were applied at weekly intervals uniformly over the whole experimental area irrespective of plant spacing or whether the plants were single-stemmed or multi-stemmed. Nitro-chalk and a proprietary potash-phosphate compound fertiliser were each applied at the rate of 1 oz. per square yard each week from planting. The amount of water applied varied throughout the season, the criterion being the visual one that the soil, as indicated by auger borings, should be very moist, down to a depth of 3 ft., from the date of planting onwards (i.e., ball watering was not practised).

The seed was sown in John Innes Seed Compost on December 22nd, potted up in John Innes Potting Compost No. 2 in 3 in. pots on December 29th, and planted out on February 12th, when the first truss was just visible. At this stage the roots were well out to the edge of the pots, but the plants were far from being "pot-bound".

All the shoots (main stems on single-stemmed plants and main stems and axillary shoots on multi-stemmed plants) were stopped as near to June 2nd as was possible.

Picking was carried out daily (excluding Sundays). The fruit was weighed in bulk on a treatment-plot basis, but the colour grade of each fruit was recorded individually according to the system already outlined (2).

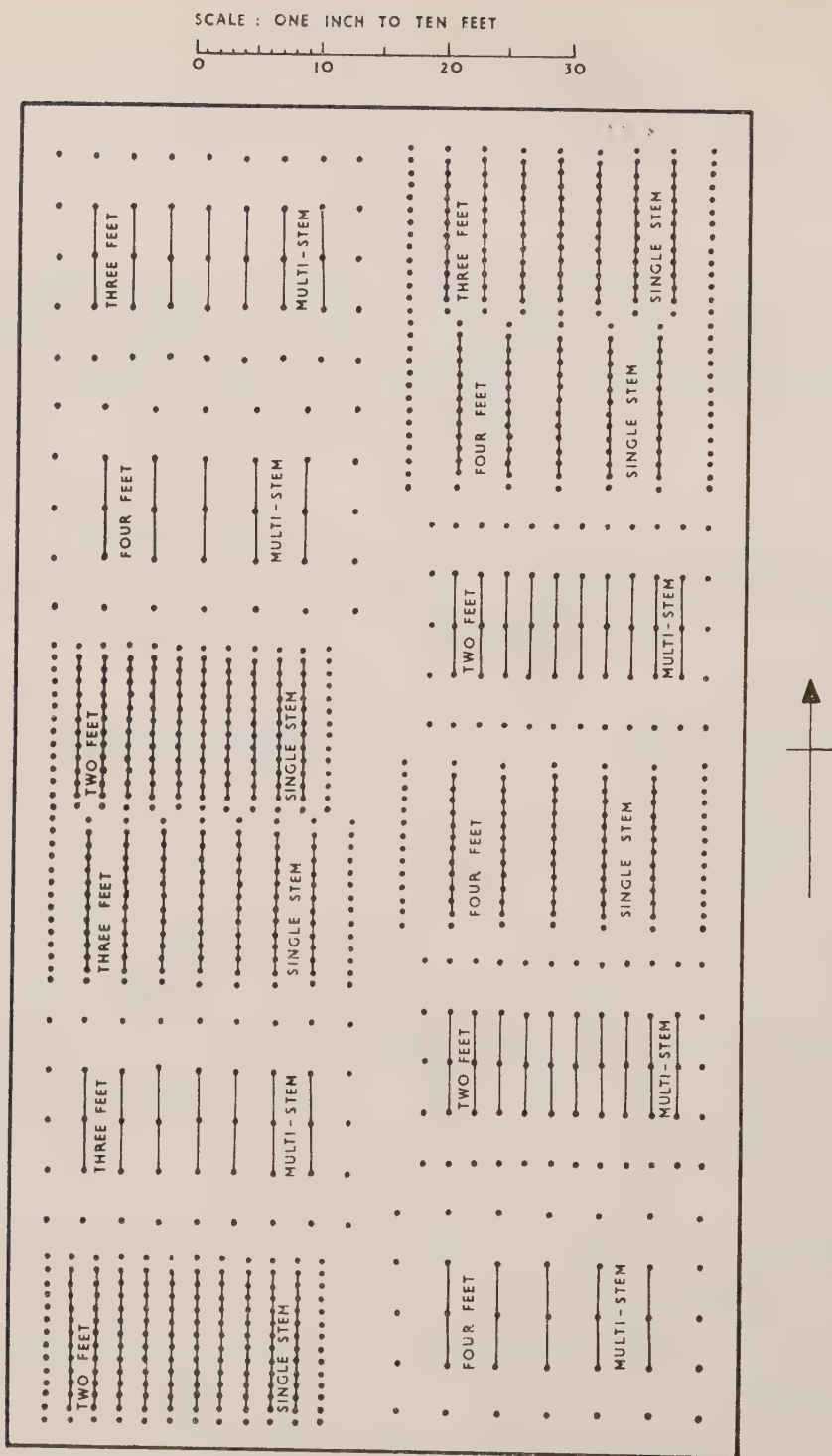


FIGURE 1. Plan of Pruning-Spacing Trial.

Results

The weight of fruit picked, in grams per sq. ft. of greenhouse soil, is shown in Table I. Also shown for each treatment is the mean fruit weight and the percentage of fruit that was uniformly coloured. The grading for uniformity of colouring was extremely strict, and fruit that had the slightest trace of uneven colouring were rejected from the uniformly coloured grade.

TABLE I
YIELD OF FRUIT WITH MEAN FRUIT WEIGHT AND PERCENTAGE
UNIFORMLY COLOURED, FROM SINGLE- AND MULTI-STEMMED PLANTS
AT THREE PLANTING DENSITIES.

Pruning treatment	Spacing treatment	Weight of fruit picked	Mean fruit weight	Uniformly coloured fruits
		<i>g./sq. ft.</i>	<i>g.</i>	<i>%</i>
Single-stemmed	2 ft.	1,534	45	50.4
	3 ft.	1,466	47	45.0
	4 ft.	1,244	45	45.4
Multi-stemmed	2 ft.	1,189	48	53.9
	3 ft.	1,238	52	50.0
	4 ft.	1,223	53	50.3

The greatest yield per square foot of glasshouse soil was obtained from the single-stemmed plants at the two closest spacings. There was no significant difference (at $P = 0.05$) between the yields from these two spacings, although the yield from the 2 ft. spacing tended to be greater than that from the 3 ft. spacing. Both these yields were significantly greater ($P = 0.05$) than those from the multi-stemmed plants at all spacings and from the single-stemmed plants at the wide spacing.

There was no significant difference between the yields from the multi-stemmed plants at any of the spacings, nor did these yields differ from that of the single-stemmed plants at the wide spacing.

The multi-stemmed plants at the two widest spacings bore fruit with a mean individual fruit weight that was significantly greater ($P = 0.05$) than the general mean for all treatments. The mean individual fruit weight of the multi-stemmed plants at the closest spacing did not differ significantly from the general mean for all treatments. The fruit of the single-stemmed plants at all spacings had a mean individual weight that was significantly lower ($P = 0.05$) than the general mean for all treatments.

Neither the spacings tested nor the retention of axillary shoots had any significant effects ($P = 0.05$) on the weight per unit area of early fruit picked. The criterion of earliness used was arbitrarily chosen as the weight of fruit picked during the period of twenty-nine days from the date of picking of the first ripe fruit.

The single-stemmed plants yielded a significantly lower percentage of uniformly coloured fruit ($P = 0.05$) than did the multi-stemmed plants, except at the closest spacing. At this spacing there was no significant difference between the single and the multi-stemmed plants, although the multi-stemmed plants tended to yield a higher percentage of uniformly coloured fruit than did the single-stemmed plants.

In spacing trials the treatments must necessarily occupy considerable space, and the replications in the experimental layout are consequently few because of limitations of space. It is thus difficult to obtain significant differences between treatments, without lowering the probability level, unless the actual treatment differences are very large. Consequently, despite the absence of significance at the 5% level of probability, a consideration of the trends in the data is not completely valueless. In Table II are shown the weights of "early" fruit picked in grams per square foot.

TABLE II
WEIGHT OF EARLY FRUIT PICKED FROM SINGLE- AND MULTI-STEMMED
PLANTS AT THREE PLANTING DENSITIES

Pruning treatment	Spacing treatment	Weight of early fruit picked <i>g./sq. ft.</i>
Single-stemmed	2 ft.	443
	3 ft.	557
	4 ft.	639
Multi-stemmed	2 ft.	166
	3 ft.	220
	4 ft.	65

Although there were no consistent trends in the effects of the spacing treatments on early yield it can be seen that single-stemmed plants tended to bear a greater weight of early fruit per unit area of glasshouse than did multi-stemmed plants.

To summarise, the data indicate that single-stemmed plants at the closest spacing tested (21,780 plants/acre) gave the greatest weight of fruit per unit area of glasshouse. If a reduction in mean fruit size and an increase in the percentage of uniformly coloured fruit borne is regarded as an improvement in quality in "Potentate", the data also indicate that the single-stemmed plants at the closest spacing bore fruit of as high a quality as any other treatment tested. There was also a tendency for single-stemmed plants to bear a greater weight of early fruit per unit area.

When considered in relation to the literature review on spacing, given later in this report (see p. 36), the above data neither support nor refute the hypothesis that yield per unit area increases with planting density, since, although there was an actual increase in yield with an increase in planting density up to 21,780 plants per acre, the increased yield obtained by increasing the density above 14,520 plants per acre was not significant.

To test further whether yield per unit area increases up to the practical limit of planting density it is proposed to test the hypothesis more thoroughly in 1958 by incorporating a planting density of 24,891 plants per acre—the ultimate practical limit under glass.

This should determine for the cultural conditions used whether inter-plant competition, or factors such as ease of management, limit yield increase under glass.

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2. THE SPACING OF GLASSHOUSE TOMATOES: A CRITICAL REVIEW OF THE LITERATURE

by

A. J. COOPER

A considerable amount of work has been done by many research workers in various parts of the world in an attempt to answer the question: "How far apart should tomatoes be planted if the maximal crop per unit area of soil is desired?"

Much of the work, especially in the United States, has been carried out using unpruned, unstaked plants grown in the open. As few of the findings are applicable to single-stemmed plants it is not proposed to consider them here, but to discuss only work carried out with single-stemmed plants.

Since 1900 numerous trials on planting density have been laid down, not only in heated glasshouses but also in the open and in cold houses. It is proposed to review all these trials, as conditions within heated glasshouses in different part of the world vary so enormously that there is little justification for ignoring cold house and field trials with single-stemmed plants on the grounds that the environmental conditions are not identical with those in heated glasshouses.

Little or no work has been done on the possible existence of an inter-action between planting density and variety, and many different varieties have been used in the many trials that have been carried out: it is therefore impossible to do more than bear in mind the possibility of the existence of such an interaction when making comparisons. There appear to be little or no data available to test its magnitude, or even its existence. There is also little reference to the interaction of spacing with fertiliser application or watering.

In the various planting trials a large number of intra- and inter-row spacings have been tested; some workers have used single row planting patterns and others double row. Little attempt appears to have been made to determine whether an interaction exists between planting density and planting pattern, i.e. whether the optimal density is different for a single row and a double row planting pattern. The Cheshunt workers (Anon. 1936, 1937), while not actually concerned with testing this interaction, did test a single row pattern, with the rows 27 in. apart and the plants within the row 14 in. apart, against a double row pattern with the double rows 27 in. apart, the rows 18 in. apart and the plants within the row 18 in. apart. These distances were such that each plant occupied fairly similar areas of soil, 378 and 405 square inches in the single and double row patterns respectively. In both years the conclusion was drawn that "Statistical examination of the results indicates that the yield . . . was practically the same with the different methods of planting". It thus appears unlikely that there is an important interaction between planting pattern and planting density.

If these two interactions are disregarded, i.e. the interactions of variety and planting pattern with planting density, it is possible to compare experimental results on a basis of the area in square inches occupied by one plant. Since planting densities are not usually considered in this manner the following table gives some equivalents in terms of plants per acre.

<i>Plants/acre</i>	<i>Sq. in./Plant</i>
6,000	1,045
8,000	784
10,000	627
12,000	523
14,000	448
16,000	392
18,000	349
20,000	314
30,000	209
40,000	157

Considering first those spacing trials that have been carried out on single-stemmed tomatoes grown in the open, the closest plantings tested appear to have been those of Paul and Jayasundera (1938) who grew the variety "Marglobe" in the open in Ceylon and allowed the plants 324 and 432 sq. in. of ground each. They found that there was no difference in the yield per unit area between the two spacings. Paul and Joachim (1938) continued the work and tested spacings of 648 and 864 sq. in., drawing the conclusion that "The closer spacing gave an increased yield of 881 lb./acre which was significant at Fisher's 1% point". Woods (1940), using the "Bonny Best" variety in the open in British Columbia tested out for four years the three widest spacings of Paul, Jayasundera and Joachim—432, 648 and 864 sq. in.—and also included a wider one of 1,080 sq. in. per plant. He drew the conclusion that "a consistently higher yield is shown for close planting . . .". In 1934 Thompson had tested out the three widest spacings used by Woods—648, 864 and 1,080 sq. in. per plant, using the same variety, "Bonny Best", grown in the open in New York State, and had come to a similar conclusion, namely, that "the yield per acre increased as the number of plants increased".

Thus workers on the spacing of outdoor tomatoes are in agreement that over the range of 1,080 to 432 sq. in. per plant the yield per unit area increases as the planting density increases. Further, reducing the area per plant from 432 to 324 sq. in. had no effect on yield in the Ceylon trials with "Marglobe".

The only detailed report of a cold house spacing trial appears to be that of du Feu (1945) who tested spacings of 385, 424, 576 and 592 sq. in. per plant in England. The results are in agreement with those of the outdoor trials in that an increase in planting density gave an increase in yield per unit area and a decrease in yield per plant. Although the two greatest densities (385 and 424 sq. in. plant) were greater than the 432 sq. in. planting of the outdoor trials the yield per unit area still increased with increased density. There was thus no indication of the beginning of a failure to increase yield by further increasing the density, the phenomenon reported by Paul and Jayasundera when they increased the density from 432 to 324 sq. in. per plant. If the phenomenon were a true general effect of increased planting density it would appear from the work considered so far that it begins to occur at a density somewhere between 385 and 324 sq. in. per plant.

A larger number of trials have been carried out with heated glasshouse tomatoes, but the greater amount of work seems only to have resulted in a greater amount of confusion.

Lamm (1956), in Sweden, using densities of 465, 387 and 310 sq. in. per plant, and Nicolaisen and Fritz (1954), in Germany, using densities of 698 and 465 sq. in. per plant, reported results in agreement with those so far considered for outdoor and cold house tomatoes—the closer the spacing the greater the yield per unit area. The greatest density used by Lamm (310 sq. in. per plant), however, was greater than the density at which Paul and Jayasundera reported that they

obtained no further increase in yield with increased density. Sheard's as yet unpublished data, obtained in England, show the same trend of increasing yield per unit area with increasing density at even greater densities (638, 522, 406 and 290 sq. in. per plant). Green and Waid (1904), who used an amazing dense planting in Ohio (576, 324 and 144 sq. in. per plant), also found that yield per unit area increased as planting density increased. They stated that plants "set one foot apart each way gave the highest yield per square foot with a loss of nearly one ounce in average size of fruit". The practical difficulties of working such a dense planting must have been enormous. Recently, however, workers in Denmark (Anon. 1954) have also reported that, over three years, plants with 154 sq. in. of glasshouse space have given greater early and total yields than plants grown with 256 sq. in.

Thus from the work considered so far it would seem feasible to draw the conclusion that for outdoor, cold house and heated glasshouse tomatoes the greater the planting density the greater the yield per unit area. It would therefore seem that the limiting factor in increasing planting density is the practical one of what constitutes the closest convenient planting distance for cultural operations.

Zimmerley (1919), however, using "Bonny Best" in Virginia, found that increasing the density from 900 to 720 sq. in. per plant increased the yield per unit area, but that increasing the density further to 540 sq. in. per plant gave no further increase. The Cheshunt workers (Anon. 1937), using "Ailsa Craig", found that increasing the density from 486 to 405 sq. in. per plant increased the yield per unit area but further increases in density to 378 and 315 sq. in. had no further effect, the yield being the same as at 405 sq. in. per plant.

Three workers have reported the findings of optimal planting densities for glasshouse tomatoes; densities greater than the optimum producing decreases in the yield per unit area. These are Hoffman (1932), Seaton (1934), and Lockie and Butters (1956), who reported optimal densities of 480, 784 and 450 sq. in. per plant respectively. Hoffman worked in Ohio and used densities of 384, 480 and 576 sq. in. per plant. Seaton using the "Grand Rapids Forcing" variety, tested densities of 392, 588, 748, and 1176 sq. in. per plant in Michigan. Lockie and Butters, working in England and using "Ware Cross", tested densities of 390, 420, 450, 480 and 510 sq. in. per plant.

Hockey and Ball (1955) compared "Potentate" at 315 and 405 sq. in. per plant over two years in an un-replicated trial in New Zealand and reported an increase in yield per unit area with a *decrease* in planting density.

There is thus considerable confusion in the literature in the replies to the question: "How far apart should tomatoes be planted if the maximal crop per unit area of soil is desired?" This may be due to the fact that no one appears to have tested the existence for single-stemmed plants of an interaction between planting density and the amount of fertiliser applied. This problem is more complex in the tomato than in many other crops because top dressings are applied in addition to a base dressing. Vittum and Tapley (1953), using unpruned, unstaked tomatoes grown in the open in New York State, did some work on this interaction and stated that "it is evident that for both early and total yield, larger responses to applied fertiliser were obtained at the 10 sq. ft. spacing than were obtained at the $12\frac{1}{2}$ or the 15 sq. ft. spacing. Conversely, responses to the closer spacing were greater at the high fertility level than they were at the low fertility level". While not directly applicable to single-stemmed plants these results suggest that those workers who reported either no further effects or decreased yields with further increases in planting density above so-called "optimal" densities, may not have been applying adequate fertiliser to support the denser plantings. The operation of such a limiting interaction is suggested by the fact that the "optimal" densities reported differ one from the other, e.g., Anon (1937), reported an optimum between 486 and 405 sq. in. per plant; Hoffman (1932) reported an optimum of 480 sq. in. per

plant although later (1938) he recommended an optimum of 720 sq. in. per plant. Lockie and Butters (1956) reported an optimum of 450 sq. in.; Seaton (1934) one of 784 sq. in., and Zimmerley (1919) reported an optimum between 900 and 720 sq. in. per plant.

The interpretation must remain debatable whether those workers who reported increased yields per unit area with increased planting density were applying adequate fertiliser and/or water to support the increased yield at the increased densities, while those workers who failed to obtain increased yields were not doing so. The consequent confusion will persist until the interaction of manurial treatment, watering rate and planting density is determined.

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III. CHEMISTRY

1. STUDIES OF THE COMPOSITION OF TOMATO FRUIT

by

G. W. WINSOR & D. M. MASSEY

Studies of the composition of tomato fruit in relation to fruit quality, state of ripeness and variety, based on procedures for the examination of the expressed fruit juices as previously described (1, 4), have been continued and extended. Earlier studies led to the conclusion that fruit quality is in general related to the dry-matter content of the fruit, and that the latter property is closely correlated with the total concentration of soluble solids in the expressed sap. Apart from the overall concentration of soluble matter in the sap, the proportions of the main constituents affect the flavour of the fruit. Among the various compounds present reducing sugars constitute by far the most important fraction numerically, and the concentrations of sugar in the sap are thus closely correlated with values for total solids and for percentage dry matter in the fruit. The most noticeable source of variation in the flavour of tomatoes appears, however, to be the degree of acidity. For many purposes it is thus possible to simplify the earlier schemes of analysis of the expressed sap, concentrating on total solids content, sugars and titratable acidity. Still more rapid physical methods relating to the content of soluble solids may prove particularly useful where large numbers of samples are involved, as will be discussed subsequently.

The results which follow form a progress report on various aspects of these investigations, the main topics discussed being:—

- (a) The composition of tomato fruit in relation to its grading based on external characteristics.
- (b) The composition of the free juices from tomato loculi, and its relation to sap expressed from the outer fruit walls.
- (c) Further studies of changes in the fruit walls during ripening.
- (d) Comparison of the composition of fruit of two varieties ("Potentate" and "Immuna"), each grown on 36 plots in an experiment on magnesium deficiency.
- (e) Use of the hand refractometer for the examination of tomato juices.

In addition to the foregoing studies, briefly described under their separate headings, the procedures for examining expressed sap were also applied to fruit from plants having varying proportions of their foliage removed. The results, together with data for total sugar-content of the fruit and observations on cropping and fruit quality, are given in a separate paper in this Annual Report.

The composition of fruit of variety "Potentate" in relation to grading and fruit quality

In previous studies (1, 3, 4) it has repeatedly been shown that tomatoes showing yellow-green ("blotchy") or colourless ("waxy") areas in the walls have a lower content of total solids, sugars and acids in their expressed sap than do normally-ripened fruit from the same picking. In 1957 the opportunity was taken to extend such comparisons to include fruit graded into a wide range of categories. Definitions of grades A—D are given in the article on magnesium deficiency in the present Report (p. 99); for the purpose of the studies now described grade D was restricted to irregularly shaped fruit containing numerous loculi and thus having a "folded" appearance in the outer walls, but showing normal pigmentation. In addition, fruit of grade C was subdivided into a further series of categories, of which those selected for analytical studies were as follows:—

- C1. Fruit showing green or yellow-green areas anywhere in the walls against an otherwise normal orange to orange-red background, this irregularity of pigmentation being classed as of slight or medium severity. Such fruit would normally be expected to become relatively uniform in colour when further ripened.
- C2. Fruit showing green or yellow-green areas as above, but to a more severe degree. Such fruit usually showed some abnormality in the fruit walls when cut open, and would never be acceptable as of good quality even when fully ripened.
- C4. Fruit showing a shading of deep green colour surrounding the calyx, but no other abnormality. Such green pigmentation was of a deeper colour than that typical of "blotchy" areas in fruit walls or of the general colour of green fruit prior to pigmentation, and the areas showing this dark pigmentation were not hard and immature.
- C5. Fruit having a paler colour in the upper half, surrounding the calyx, than the normal orange-red of the remainder of the fruit; the colour of the pale areas was yellow-orange, frequently with a somewhat creamy tint. Much of the fruit in this category would be quite uniformly coloured when fully ripened, though not so at the time of packing. Some of the fruit, however, showed discoloured, spongy areas in the walls when cut.
- C6. Fruit showing colourless or "waxy" areas in the outer walls, these generally occurring in the upper half of the fruit. Such fruit invariably showed internal damage associated with the vascular strands in the walls, and frequently showed surface depressions or pitting in severely affected areas. Fruit in this category is severely damaged and never ripens normally.

Fruit graded into these and other categories was analysed on numerous occasions during the season. Not all categories were necessarily represented adequately, or even at all, at all times throughout the season. Thus, for example, the deep green shading of category C4 was rare in the early stages of cropping but became more obvious later. The severely affected fruit of category C6 was rarely encountered in quantity after mid-season. The data presented in Tables I to III have been limited to the six dates of sampling at which categories A, B, C1, C2, C4, C5 and D were all adequately represented simultaneously. The statistical analyses relating to the Tables are based entirely on these seven grades; analytical data for category C6, represented at the first four dates of sampling, have also been included in the Tables in view of their interest, but have been omitted from the statistical calculations because of missing values at the last two dates of sampling.

The results for soluble solids in the expressed sap are given in Table I; the mean values for the season show little difference in concentration between categories A, B, and D. Thus irregularity

TABLE I
SOLUBLE SOLIDS (g./100 ml.) IN SAP EXPRESSED FROM VARIOUS
GRADES OF FRUIT (VARIETY: "POTENTATE")

Date of sampling	Grade of fruit							
	A	B	C1	C2	C4	C5	D	C6*
28th May	4.25	4.19	3.94	3.55	4.26	3.64	3.90	3.28
4th June	4.69	4.73	4.02	4.02	4.37	3.59	4.48	3.45
14th June	4.79	4.51	3.93	4.00	4.88	4.04	4.31	3.59
25th June	4.63	5.20	4.22	4.21	5.99	4.20	4.93	3.99
19th July	5.34	5.01	4.86	4.63	5.95	4.56	5.19	—
26th July	4.91	4.62	4.56	4.75	5.57	4.51	5.08	—
Mean	4.77	4.71	4.26	4.19	5.17	4.09	4.65	

*Excluded from the statistical analysis

of shape did not significantly change the concentration of sap solids. Grades C1 and C2, typifying moderate and severe blotchy ripening, showed significantly lower concentrations of soluble solids than were present in evenly coloured fruit, as also did the pale-topped fruit of category C5. The "waxy" fruit of grade C6, excluded from the statistical analyses, showed the lowest concentrations of soluble solids encountered during the investigations. Perhaps the most striking feature of the results was, however, the relatively high values found for the green-shaded fruit of category C4, these being significantly higher than for fruit of categories A and B.

The results for sugars in the sap (Table II) show a very similar trend to those in Table I. Thus irregularities of shape (grades B and D) were not accompanied by any significant decrease in sugar content, but fruit showing green areas in the walls (C1 and C2) or a relatively pale colour in the upper half (C5) contained, on the average, markedly less sugar than grade A. The "waxy" fruit of grade C6 gave the lowest values of all at any one date of sampling, and again the highest values in the table relate to category C4, that is, to fruit with deep green shading around the calyx.

TABLE II
SUGARS (g./100 ml.) IN SAP EXPRESSED FROM VARIOUS GRADES OF
FRUIT (VARIETY: "POTENTATE")

Date of sampling	Grade of fruit							
	A	B	C1	C2	C4	C5	D	C6*
28th May	2.75	2.66	2.38	2.20	2.50	2.14	2.49	1.91
4th June	3.08	3.19	2.46	2.66	2.65	2.17	2.98	1.83
14th June	3.32	3.16	2.34	2.37	2.99	2.38	2.83	2.16
25th June	2.99	3.29	2.72	3.06	4.09	2.66	3.28	2.47
19th July	3.40	3.17	3.20	3.10	4.00	3.84	3.38	—
26th July	3.33	2.97	2.98	3.22	3.91	2.74	3.49	—
Mean	3.15	3.07	2.68	2.77	3.36	2.66	3.08	

*Excluded from the statistical analysis

Results for titratable acidity of the expressed sap are given in Table III. A moderate degree of irregularity of shape (grade B) had no consistent effect upon acidity as compared with grade A, but the multi-locular fruit of grade D had a somewhat lower acidity; the latter result was not statistically significant, but only at the last date of sampling was the acidity of grade D fruit not lower than the corresponding grade A. Irregularly coloured fruit of categories C1 and C2 showed significantly lower values for acidity as compared with grades A and B, and grade C6 gave by far the lowest values of all. Once again the deep green-shaded fruit of category C4 showed the highest values in the Table, being significantly more acid than the uniformly coloured fruit of grade A.

Refractometer readings on the expressed sap gave results following a similar pattern to the data for sap solids in Table I.

The main conclusions arising from these results may be summarized as follows. A moderate degree of irregularity of shape was not accompanied by any obvious changes in composition as compared with regularly shaped fruit. Multi-locular fruit of highly irregular shape had a normal sugar content in the expressed sap, but tended to have a lower acidity and hence a higher sugar/acid ratio. The latter effect may be due to the presence of a higher proportion of internal fruit walls, the acidity of the walls being lower than that of the locular contents. "Blotchy" and "waxy" fruit had a lower acidity and lower content of sugars and total solids than normal fruit, as has been shown previously (1, 3, 4). Pale-topped fruit contained significantly less sugars and

total soluble solids than fruit of grade A. Fruit classified as grade C4, showing deep green shading around the calyx, gave the highest mean values of all for sugars, titratable acidity and total solids in the sap; though not conforming to the definition normally associated with top-grade fruit, such fruit appears analytically to be of the highest quality.

TABLE III
THE TITRATABLE ACIDITY (ml. N/10 alkali per 10 ml. sap) of
VARIOUS GRADES OF FRUIT (VARIETY: "POTENTATE")

Date of sampling	Grade of fruit							
	A	B	C1	C2	C4	C5	D	C6*
28th May	7.7	7.9	7.1	6.2	9.1	7.4	7.3	6.2
4th June	7.7	8.0	7.3	5.8	8.3	6.7	7.1	6.6
14th June	8.9	8.0	8.3	8.0	10.1	7.9	8.1	6.6
25th June	9.2	9.3	7.9	6.4	10.9	9.0	9.1	6.9
19th July	10.1	9.8	9.2	7.8	10.9	9.5	9.8	—
26th July	8.1	8.5	7.4	7.7	8.9	9.1	8.2	—
Mean	8.6	8.6	7.9	7.0	9.7	8.3	8.3	

*Excluded from the statistical analysis

The composition of the free juices from tomato loculi, and its relation to sap expressed from the outer fruit walls

Recent investigations have shown considerable variation in the composition of sap expressed from tomato fruit of different grades and varieties; in particular, "blotchy" or "waxy" fruit showed lower concentrations of sugars and acids in the expressed sap than did normally ripened fruit. The symptoms associated with these disorders of the ripening fruit became apparent in the outer fruit walls, and it was thus of interest to find whether the observed differences in composition of whole fruit arose entirely in the walls, or whether the inner portions of the fruit were also affected. The relation of the composition of sap expressed from the fruit walls to that of the contents of the loculi was therefore investigated. For this purpose the outer walls were separated from the inner portions of the fruit and frozen prior to expression of the sap; the juices from the inner portions of the fruit were strained off and centrifuged before analysis.

The 49 samples examined included fruit of varieties "Potentate" and "Immuna", ranging from the best quality (grade A) to poor quality fruit showing vascular browning and irregular pigmentation. As an example of the results obtained, the data for six samples of variety "Potentate" are shown in Table IV. All six batches of fruit were from a single picking from house C4, graded as already defined. In addition to illustrating the relation between walls and free juices, the results also serve to extend previous data on the composition of different grades of fruit. The fruit listed as "poor grade A" was of regular shape and free from the obvious irregularities of pigmentation characteristic of "blotchy" or "waxy" fruit; such fruit would be acceptable commercially among the "Pink" and "White" grades, but was separated out on the basis of firmness and general appearance.

The results show that the free juices of the tomato are markedly more acid than sap expressed from the outer fruit walls, and have a higher ratio of acid to sugar. The highest values for total solids, sugars and acidity, both in the free juices and in the walls, were found for Grade A fruit. Fruit described in the Table as "poor grade A" was definitely inferior in composition, as also were samples showing uneven colour (C1, 2, 5, 6). Analysis of fruit showing pale colour in the upper parts adjoining the calyx (C5) showed relatively low values, particularly for sugars and total

TABLE IV

THE COMPOSITION OF THE FREE JUICES FROM DIFFERENT GRADES OF FRUIT OF VARIETY "POTENTATE", TOGETHER WITH DATA FOR SAP EXPRESSED FROM THE CORRESPONDING OUTER FRUIT WALLS (HOUSE C4, 1957)

Grade of fruit	Total solids, (g./100 ml.)		Sugars (g./100 ml.)		Titratable acidity (ml. N/10 alkali)	
	Juices	Walls	Juices	Walls	Juices	Walls
A	4.58	3.81	2.29	2.75	13.2	5.4
Poor A	3.98	3.58	1.87	2.59	10.9	4.9
C1	4.03	3.56	2.11	2.59	11.2	4.6
C2	3.91	3.37	1.92	2.44	11.0	4.6
C5	3.81	3.14	1.86	2.14	9.8	4.9
C6	3.42	3.07	1.65	2.15	8.7	3.9

solids in the outer walls; these results were somewhat unexpected, since fruit of this type became increasingly uniform in colour as ripening proceeded. The lowest analytical values of all were found for "waxy" fruit of grade C6.

The overall ranges of analytical values for total solids, sugars and titratable acidity are shown in Table V. The results include those for grade A fruit of both "Potentate" and "Immuna", but more of the samples of poor quality fruit were of variety "Potentate".

TABLE V

OVERALL RANGES OF VALUES FOR TOTAL SOLIDS, SUGARS AND TITRATABLE ACIDITY IN THE FREE JUICES OF TOMATO FRUIT. AND IN SAP EXPRESSED FROM THE OUTER WALLS

	Potentate		Immuna	
	Juices	Walls	Juices	Walls
Total solids (g./100 ml.)	3.42—5.24	2.81—5.43	4.58—5.51	4.42—5.66
Sugars (g./100 ml.)	1.65—3.16	1.81—3.99	2.35—3.22	3.13—4.15
Titratable acidity (ml. N/10 alkali per 10 ml. sap)	8.1 —16.0	2.6 —5.6	15.9—20.2	4.6 —6.7

Note. The analyses are based on 36 samples of variety "Potentate" and 13 samples of "Immuna"

The results in Table V show very considerable variation between samples, the latter ranging from first quality fruit to fruit classed as "blotchy" or "waxy". The lowest values in the Table were in every case obtained for fruit of the variety "Potentate", and the highest for "Immuna". The free juices of variety "Immuna" showed a relatively high acidity, whereas the acidity of the walls of some samples of "Potentate" was outstandingly low.

On correlating the analytical data for free juices and for sap expressed from the fruit walls of all 49 samples, the following results were obtained:—

<i>Factor</i>	<i>Correlation coefficient (r)</i>	<i>Significance (P)</i>
Total solids (g./100 ml.)	0.889	0.001
Sugars* (g./100 ml.)	0.769	0.001
Titrateable acidity	0.622	0.001

*Data for 48 samples only available.

Thus for all three tests the composition of the free juices was related to that of sap expressed from the corresponding fruit walls, the correlations being highly significant throughout. The lowest degree of correlation was found between the acidity of the walls and free juices. Examination of the acidity data for the two varieties separately shows a significant correlation for "Potentate", but not for "Immuna"; the latter result is probably due to the restricted range of acidity values found among samples of "Immuna".

The general conclusion from these results is that the effects of fruit disorders apparent in the outer walls are not confined to the latter, but are also reflected in the composition of the inner portions of the fruit.

Changes in the composition of tomato fruit during ripening

Studies of the ripening processes in tomato fruit have already been referred to in previous Reports (2, 3). Examination of the expressed sap of whole fruit showed consistent trends during ripening, the concentrations of sugars and total soluble solids rising as the fruit matured and the titrateable acidity reaching its maximum at the first appearance of yellow-orange pigmentation and declining subsequently. Studies of sap expressed from the outer fruit walls showed similar trends for sugars and total solids, but the data for titrateable acidity were very variable. Thus in some experiments the acidity increased from the green to the red stage, in other cases acidity decreased after the first appearance of the yellow colour, as in the whole fruit, while some graded series showed no consistent trends at all during ripening.

Further series of fruit were therefore examined during 1957, with the primary object of establishing the trend of changes in titrateable acidity during ripening of the outer fruit walls. The opportunity was also taken to confirm previously established trends in sugars and total solids, and to obtain more complete data for the free juices within the loculi of the fruit. The results for sap expressed from the outer fruit walls of variety "Potentate", grouped into five categories on the basis of colour, include ten series of tests on fruit from houses D1 and D2 and three series from house C1. Data for total solids, sugars and titrateable acidity are given in Tables VI—VIII.

The results for total solids and sugars in the walls both show increasing concentrations throughout the course of ripening from the green to the red stage; these trends are similar to those previously reported and need not be discussed further. The data for titrateable acidity (Table VIII) show that, at every date of sampling, it increased from the green stage to the first appearance of yellow pigmentation. No consistent trend in acidity of the walls is apparent as ripening continues, however, despite the considerable number of samples examined.

The results for acidity of the fruit walls are in marked contrast to those for juices obtained from the inner portions of the fruit. The data in Table IX include results for juices from the locular contents after squeezing by hand through butter-muslin (I), juices freely drained from the fruit after removal of the outer walls (II), and juices separated from the contents of the locules through a gauze strainer (III); in every case the samples were taken shortly after dissecting the fresh (unfrozen) fruit.

TABLE VI

TOTAL SOLIDS (g./100 ml.) IN THE EXPRESSED SAP OF WALLS OF
TOMATO FRUIT AT DIFFERENT STAGES OF RIPENESS

Date of sampling	Stage of ripening				
	1 Green	2 Green- Yellow	3 Yellow- Orange	4 Orange- Red	5 Red
29th May	3.37	3.23	3.51	3.53	3.45
19th June	4.18	4.44	4.30	4.27	4.30
19th June	4.16	4.32	4.37	4.30	4.63
3rd July	3.98	4.55	4.70	4.54	4.67
10th July	3.43	3.88	4.34	4.02	4.37
10th July	4.06	4.54	4.63	4.43	5.24
17th July	3.81	4.26	4.19	4.55	4.41
17th July	4.03	4.14	4.54	4.69	4.92
18th July	3.89	4.71	4.66	4.57	5.20
29th July	3.74	4.41	4.59	4.80	5.38
14th August	3.97	4.62	4.70	4.95	4.85
26th August	4.27	4.49	4.63	4.73	4.95
19th September ..	4.45	5.04	5.09	5.12	5.51
Mean	3.95	4.36	4.48	4.50	4.76

TABLE VII

REDUCING SUGARS (g./100 ml.) IN THE EXPRESSED SAP OF WALLS OF
TOMATO FRUIT AT DIFFERENT STAGES OF RIPENESS

Date of sampling	Stage of ripening				
	1 Green	2 Green- Yellow	3 Yellow- Orange	4 Orange- Red	5 Red
29th May	2.29	2.09	2.53	2.46	2.33
19th June	3.22	3.36	3.07	3.22	3.06
19th June	3.17	3.26	3.08	3.19	3.38
3rd July	2.75	3.20	4.01	3.08	3.19
10th July	2.45	2.83	3.32	2.91	3.06
10th July	2.87	3.19	3.25	3.09	3.70
17th July	2.68	3.00	2.88	3.26	3.03
17th July	2.71	2.82	3.22	3.01	3.24
18th July	2.91	3.52	3.50	3.44	3.90
29th July	2.68	3.15	3.27	3.54	3.94
14th August	2.97	3.43	3.52	3.67	3.58
26th August	3.17	3.26	3.42	3.50	3.73
19th September ..	3.45	3.86	4.08	3.98	4.22
Mean	2.87	3.15	3.32	3.26	3.41

TABLE VIII

THE TITRATABLE ACIDITY* OF THE EXPRESSED SAP OF WALLS OF
TOMATO FRUIT AT DIFFERENT STAGES OF RIPENESS

Date of sampling	Stage of ripening				
	1 Green	2 Green- Yellow	3 Yellow- Orange	4 Orange- Red	5 Red
29th May	4.4	5.1	4.9	5.2	5.4
19th June	3.7	5.3	6.0	5.7	5.6
19th June	4.2	5.4	6.2	5.8	6.1
3rd July	5.4	6.8	7.0	7.0	6.7
10th July	4.7	6.1	6.7	6.1	7.2
10th July	6.1	7.1	6.9	6.7	6.9
17th July	4.9	6.3	6.1	6.7	6.5
17th July	5.8	5.9	6.8	7.0	6.9
18th July	3.6	5.6	5.6	5.1	6.1
29th July	4.1	5.5	5.4	5.5	5.3
14th August ..	4.8	6.0	5.8	5.9	6.1
26th August ..	5.0	5.9	5.8	5.7	4.9
19th September ..	4.1	5.1	4.9	4.9	5.2
Mean	4.7	5.9	6.0	5.9	6.1

*Ml. N/10 alkali per 10 ml. sap

The results in Table IX show clearly that the acidity of the locular juices is high, and decreases markedly as the fruit ripens. In five out of seven of the series included in the Table the acidity decreased progressively from mature green to red, whilst in the remaining two series it increased slightly from green to yellow-green and then decreased subsequently as in the other series. The decrease in acidity of the free juices during ripening was also demonstrated for two series of fruit of variety "L.M.R. 1"; this variety showed a high acidity, the titration values (ml.N/10 alkali per 10ml. of sap) ranging from 34.3 to 29.2 for the mature green fruit to 27.0 and 19.8 when fully ripe.

TABLE IX

THE TITRATABLE ACIDITY (ml. N/10 alkali per 10 ml. sap) OF JUICES
FROM THE INNER PORTIONS OF TOMATO FRUIT (VARIETY: "POTENTATE")
DURING RIPENING

Date of sampling*	Method of preparation**	Stage of ripening				
		1 Green	2 Green- Yellow	3 Yellow- Orange	4 Orange- Red	5 Red
3rd July	I	19.1	19.0	17.8	17.7	16.4
3rd July	I	16.6	17.1	14.9	14.2	11.0
10th July	I	21.0	19.5	17.9	16.0	14.7
10th July	I	20.6	17.4	16.7	15.8	15.4
29th July	II	17.8	18.4	16.7	15.1	13.8
26th Aug.	III	20.3	19.9	17.1	16.4	13.8
19th Sept.	III	19.8	17.9	15.9	13.9	14.7

* The second series of fruit dated 3/7/57 was from pot-grown plants, all others being from D Block. The two series dated 10/7/57 were from plots receiving different manurial treatments.

** The numbers I—III refer to the three different procedures used in the preparation of the sap samples, as described in the text.

In contrast to the values for titratable acidity, the sugar content of the free juices increased steadily during ripening (Table X); values for total soluble solids reflect the balance of these two opposing trends, and show some increase during ripening, particularly between the first and second stages of the Table.

TABLE X
CHANGES IN THE CONCENTRATION OF SUGARS AND TOTAL SOLIDS IN
THE FREE JUICES OF TOMATO FRUIT (VARIETY: "POTENTATE") DURING
RIPENING

	Date of sampling	Stage of ripening				
		1 Green	2 Green-Yellow	3 Yellow-Orange	4 Orange-Red	5 Red
Sugars (g./100 ml.) ..	26/8/57	2.11	2.30	2.46	2.54	2.75
" " " " " "	19/9/57	2.45	3.00	3.23	3.34	3.36
Total solids (g./100 ml.)	26/8/57	4.62	4.81	4.88	4.96	4.86
" " " " " "	19/9/57	4.76	5.18	5.26	5.25	5.35

In view of differences in the trends for titratable acidity in the outer fruit walls during successive seasons (see Ann. Rep. 1954-1955, Tables III and VI, pp. 57-58; 1956, Table XVII, p. 61; 1957, Table VIII, p. 47) it was considered necessary to establish that changes in the sap expressed from whole fruit during ripening in 1957 followed the general trends as previously established. The results for total solids, sugars and titratable acidity are given for two series of graded fruit samples (variety: "Potentate") in Table XI.

As in previous seasons, the concentrations of sugars and total solids in the sap increased during ripening. Values for titratable acidity decreased throughout ripening in one series and from the maximum at the first appearance of yellow colouration in the other series. The only point of difference in the titratable acidity of the two series lies in the location of the maximum at the first or second stage of ripeness in the Table; this minor variation has been noted previously, and is probably due to differences in visual grading of the samples at stages close to maximum acidity in the fruit. As the greatest changes in acidity occur in the internal portions of the fruit and visual grading is based on external colour, it is also possible that the colour of the walls is not a sufficiently precise guide to the onset of ripening within.

To summarize these and previous data on the changes in composition of tomato fruit during ripening, the trends in total solids, sugars and acidity in sap expressed from whole fruit and in the free juices from the loculi are now clearly established, as are those for total solids and sugars in sap from the outer fruit walls. With the exception of two series of fruit examined during 1955, however, no consistent trends have been established in the titratable acidity of the outer walls after the initial increase accompanying the first signs of yellow colour. This result is in contrast to the consistent differences in acidity in the variously coloured areas of the walls of blotchy fruit. The influence of physical factors such as light and temperature on the acidity of fruit walls and of whole fruit merits further attention.

Comparison of the composition of fruit of varieties "Potentate" and "Immuna"

Two varieties of tomato, "Potentate" and "Immuna", were included in the glasshouse trials on magnesium deficiency in houses D1 and 2 during 1957. Both varieties were grown in each of 36 plots, thus providing a valuable opportunity to compare the composition of the fruit with a high degree of replication of sub-plots.

TABLE XI

CHANGES IN TOTAL SOLIDS, SUGARS AND TITRATABLE ACIDITY IN
SAP EXPRESSED FROM WHOLE FRUIT

	Date of sampling	Stage of ripening				
		1 Green	2 Green-Yellow	3 Yellow-Orange	4 Orange-Red	5 Red
Total solids (g./100 ml.)	29/7/57 19/9/57	4.18 4.26	4.69 4.64	4.74 4.80	4.83 4.75	5.42 4.97
Sugars (g./100 ml.)	29/7/57 19/9/57	2.72 3.43	3.02 3.86	3.21 3.99	3.38 4.00	3.75 4.10
Titratable acidity (ml. N/10 alkali/10 ml.)	29/7/57 19/9/57	7.3 8.9	9.6 8.5	8.4 8.3	8.1 7.6	7.9 7.9

TABLE XII

ANALYSES OF SAP EXPRESSED FROM FRUIT OF VARIETIES "POTENTATE" AND "IMMUNA"

Date of sampling	Total solids (g./100 ml.)		Sugars (g./100 ml.)		Titratable acidity *		Acidity/sugar ratio **		Refractometer (% sucrose)	
	Potentate	Immuna	Potentate	Immuna	Potentate	Immuna	Potentate	Immuna	Potentate	Immuna
24th May	3.91	4.41	2.44	2.60	7.6	9.2	3.11	3.52	4.0	4.5
28th May	4.29	4.08	2.73	2.36	7.7	8.7	2.80	3.67	4.2	4.1
4th June	4.72	4.53	3.13	2.53	7.7	9.6	2.45	3.78	4.2	4.6
14th June	4.79	5.16	3.32	3.17	8.9	11.3	2.67	3.57	4.5	5.0
25th June	4.79	5.57	3.00	3.46	9.3	12.1	3.10	3.49	4.6	5.5
25th June	4.47	5.24	2.97	3.33	9.1	11.8	3.05	3.55	4.5	5.1
5th July	5.05	5.36	3.20	3.43	9.8	11.5	3.05	3.35	5.5	5.9
19th July	5.40	5.38	3.45	3.43	10.4	11.1	3.00	3.23	5.0	5.0
25th July	4.82	5.27	3.25	3.58	8.4	10.4	2.59	2.91	5.0	5.5
26th July	4.93	5.35	3.39	3.64	8.3	10.6	2.46	2.91	5.0	5.5
16th August	5.18	5.10	3.75	3.75	9.4	10.2	2.50	2.73	5.6	5.6
22nd August	5.21	5.08	3.74	3.81	9.4	9.8	2.52	2.58	5.5	5.5
20th Sept.	5.18	5.60	3.65	3.86	7.8	8.9	2.10	2.32	5.0	5.5
Mean	4.83	5.09	3.23	3.30	8.8	10.4	2.72	3.20	4.9	5.2

* Ml. N/10 alkali per 10 ml. sap.

** Ratio of milli-equivalents of titratable acids to grams of reducing sugars.

Samples of first quality fruit (grade A, as previously defined) were taken for analysis at the commercial picking stage on 13 dates between March and September, and were frozen prior to examination of the expressed sap. The results for total sap solids, reducing sugars and titratable acidity are given in Table XII, together with calculated values for the ratio of titratable acidity to sugars in the sap; for the latter purpose the acidity values have been expressed as milli-equivalents of acid. Also included in the Table are the readings obtained with a simple hand refractometer, the scale of which was calibrated in terms of percentage "sucrose" in solution; the calibration of this instrument, and its application to measurements of refractive index, are discussed in a subsequent section.

The most striking feature of the results in Table XII is the higher acidity of "Immuna" as compared with "Potentate" at all 13 dates of sampling, the mean values for titratable acidity (ml. N/10 alkali per 10 ml. sap) being 10.4 and 8.7 respectively. Values for both varieties rose to a maximum during June and July, those for "Immuna" during this period being amongst the highest we have yet found for glasshouse tomatoes. In contrast, no significant differences were found in the sugar content of the expressed sap of the two varieties; after the first few sampling dates the sugar content would be regarded as relatively high throughout, and the fruit was of good quality.

The general similarity in sugar content of the sap of both varieties, coupled with well marked differences in acidity, combine to give a significant ($P = 0.05$) but not particularly marked overall difference in content of total solids, the mean values being 4.8 and 5.1% for "Potentate" and "Immuna" respectively. Values for total solids in general reflect the trends in sugars and acids, these constituents between them accounting for about three quarters of the total soluble matter. The refractometer readings, expressed arbitrarily in terms of percentage sucrose, were closely related to values for total solids, and were significantly higher ($P = 0.01$) for "Immuna" than for "Potentate". The ratio of acidity to sugars was higher for "Immuna" than for "Potentate" at all 13 dates of sampling.

The general results of these analyses throughout the season may be summarized as follows. After the first few weeks of cropping the top-grade (A) fruit of both varieties in the magnesium deficiency trials was of particularly good quality, but the sharper, more acid flavour of fruit from variety "Immuna" was reflected in considerably higher values for acidity in the expressed sap.

Preliminary studies of the refractive index of the expressed sap of tomato fruit in relation to concentration of soluble solids

The concentration of soluble solids in the expressed sap of tomato fruit varies considerably in relation to fruit quality and variety, and is closely related to the dry-matter content of the fruit itself. The procedure used in the course of these investigations has been to determine the amounts of dissolved material in the sap by drying 10 ml. samples at 80°C. for 24 hours, the residue being weighed.

In order to speed up the examination of fruit samples, and to permit the testing of greater numbers of fruit, relatively rapid physical methods, based on the density of the solutions, have been considered for assessing the concentration of soluble materials in the sap. The most promising results, however, have been obtained by measuring the refractive index.

The refractive index of a solution increases in relation to the concentration of dissolved material, and has been used widely for rapid analysis and quality control, notably in the sugar industry; measurements of refractive index have already been reported in various investigations involving expressed plant sap. Once the sample has been expressed and centrifuged, measurements

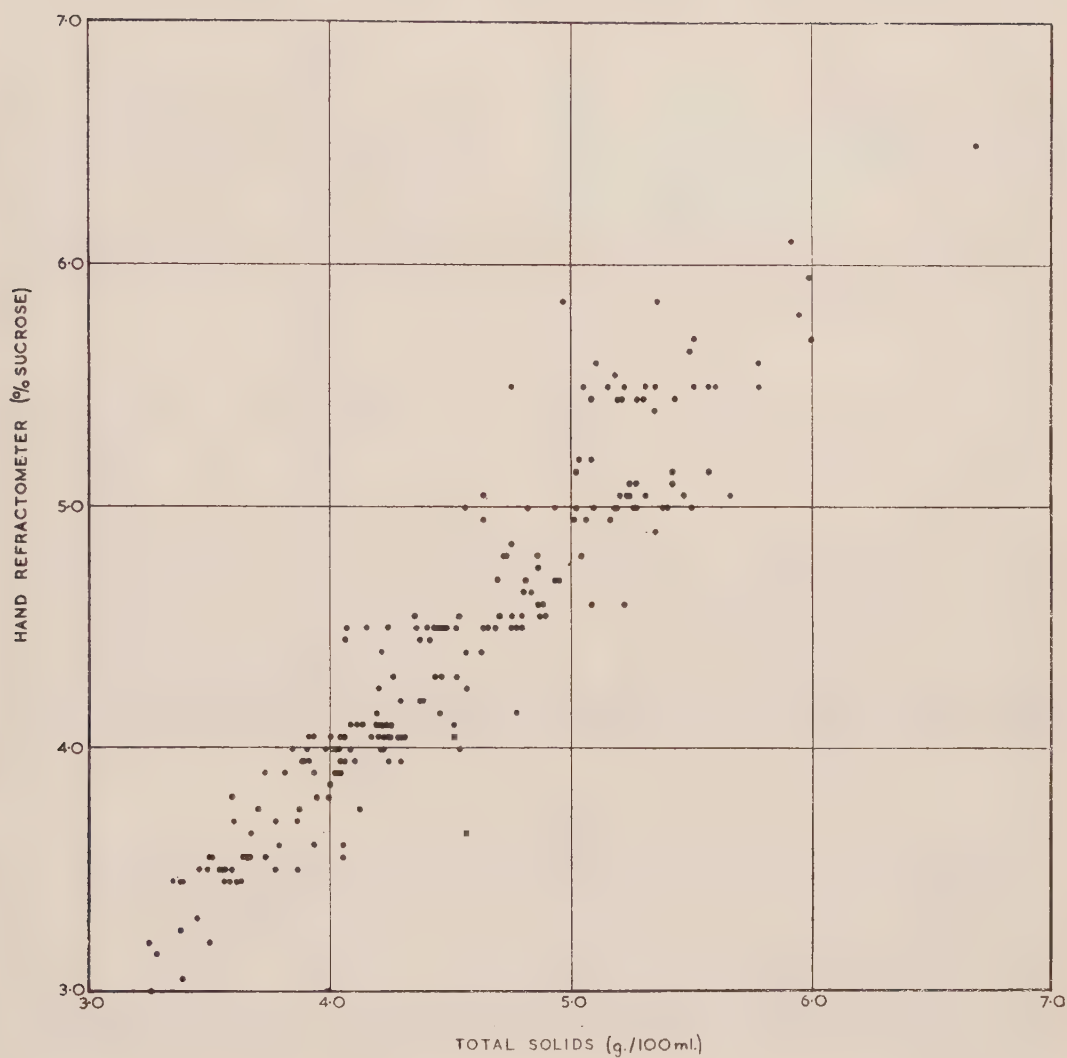


FIGURE 1. The relation between hand refractometer readings and total solids in sap expressed from ripe tomato fruit.

of refractive index can be made very rapidly. The relation between refractive index and concentration of solutions varies somewhat with the nature of the dissolved material; some 60% of the soluble material in the expressed juices of tomato fruit consists of glucose and fructose, and it seemed unlikely that variations in the proportion of the different constituents present would be so great as to obscure the general relation between total soluble solids and refractive index.

Preliminary trials on the measurement of refractive index in relation to total dissolved solids in the sap were accordingly started in 1957, the instrument available being a simple hand refractometer without means of temperature control; the instrument was calibrated in terms of the equivalent concentrations (%) of solutions of sugar (sucrose), and not directly in terms of refractive index. The numerical values obtained can, if required, be converted into readings of refractive index, but for the present purposes have been retained in their original form. Measurements of refractive index were, in general, made on all sap samples prepared throughout the season; the complete data are too numerous to reproduce here in full. Correlations between refractometer reading and total soluble solids determined by oven-drying were as follows:—

<i>Nature of sample</i>	<i>Number of samples</i>	<i>Correlation coefficient (r)</i>	<i>Significance (P)</i>
Whole fruit (ripe)	223	0.942	0.001
Outer fruit walls	167	0.926	0.001
Locular contents	27	0.944	0.001

The statistical results show a highly significant relation between total solids in the sap and refractometer readings, despite the relatively low sensitivity of the latter instrument and the lack of control of temperature during its use. One set of data is shown graphically in Figure 1; the inadequacy of the simple hand instrument is at once apparent in that the readings obtained are clearly grouped around the units and half units on the refractometer scale, all intermediate readings being by estimation. The results show very considerable promise, however, for the rapid assessment of soluble solids in tomato fruit, and further trials will be made with a more sensitive refractometer during 1958.

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2. THE EFFECT OF DEFOLIATING TOMATO PLANTS ON FRUIT COMPOSITION

by

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The demonstration in previous years of marked differences in the composition of tomato fruit (7, 8) leads to consideration of the possible causes of such differences. It seemed likely that the composition of the fruit would be affected directly or indirectly by physical factors such as light and temperature, and also by the balance of fruit and foliage present.

Unpublished studies during 1956 showed that restricting the numbers of fruit developing per truss, although markedly increasing the size of individual fruits, had relatively little effect on their composition.

Attention was therefore given to the effect of reducing the amounts of foliage on tomato plants. Since sugars and organic acids are for the most part produced in the leaves and thence translocated to the developing fruits, the composition of the fruit may be expected to vary in relation to leaf area, as has already been shown for a number of crops. Thus in apples and pears (6) a decrease in sugar content was observed after a reduction in leaf area. Similar effects have been observed for peaches (10, 11) and melons (9).

The opportunity was therefore taken to combine investigation of partial defoliation of tomato plants with laboratory studies of the carbohydrates already in progress.

Experimental methods and materials

All the tomato plants used in this investigation were grown in J.I.P. 1 compost contained in 10in. clay pots. Top-dressings of a proprietary mixed fertilizer were applied at regular intervals after the first truss had begun to swell.

Representative samples of fruit at normal commercial picking stage were collected truss by truss from the various treatments, and the titratable acidity, reducing sugars and total sap solids determined in the expressed sap by methods described elsewhere (12). The dry matter content of the fruit was also determined. Total reducing sugars soluble in hot water were determined by extracting thin, representative slices of whole fruit (50 g.) with distilled water (100 ml.) for 30 minutes on a hot-plate. The extract was filtered through glass wool and the residue washed repeatedly with small quantities of boiling water. After cooling, the combined filtrate and washings were made up to a volume of 250 ml. Reducing sugars were determined in an aliquot of the extract.

The fruit from the various treatments was also graded into four categories A-D as described in the article on magnesium deficiency in this Report (p. 99). Grade C contains all fruit showing uneven ripening, while badly shaped but otherwise normal fruit were placed in grade D. Throughout the experiment fruit belonging to grade C were further classified in eight sub-grades, of which three are of especial interest here. The sub-grades C1, C2 and C4 are defined as follows:—

- C1. Green or pale areas on an orange-red background; fruit quality otherwise good.
- C2. Very marked waxy, yellow or green areas on an orange-red background; fruit quality very poor.
- C4. Area around calyx showing deep green pigmentation, with no other defects in the fruit.

Grades C1 and C2 represent blotchy and severe blotchy or waxy fruit respectively. Grade C1, but not grade C2, will improve on further ripening. Grade C4 is distinguished from grade C1 by having deep green shading around the calyx, only, no other fault being apparent.

Three different series of defoliation experiments were carried out. For ease of presentation the results obtained are described below under separate headings, together with details of the various treatments. The varieties used were "Potentate" in Series I and II and "L.M.R. 1" in Series III.

Results

Series I

In this section of the investigation the effects of the following five treatments were studied:—

- A. The first leaf on the main stem below each truss retained and all other leaves removed.
- B. Similar to treatment A but two leaves retained below each truss.
- C. Similar to treatment A but the first three leaves retained below each truss.
- D. All leaves on the main stem retained.
- E. All leaves on the main stem retained, and in addition the lateral in the axil of the first leaf below each truss allowed to develop two leaves before being stopped.

Leaves were removed below each truss as soon as the first fruit on the truss in question had set. It should be pointed out that, except for the first and second trusses which, in general, were separated by four leaves, treatments C and D were, for the most part, identical. The treatments were begun at the end of March and continued until the end of June. By this time ten trusses had been produced on all the plants. The growing point was removed after three leaves had expanded above the tenth truss.

Ten blocks of five plants, each block containing one plant of each treatment arranged in random order, were set out in a single line running east to west along the staging of a glasshouse, with guard plants at each end.

The results for dry matter content and sugars extracted by hot water, both expressed as a percentage of the fresh fruit, are given in Tables I and II respectively. Results for sap solids, reducing sugars and the titratable acidity of the expressed sap are shown in Tables III, IV and V respectively. The dry matter content, total reducing sugars soluble in hot water, and the sap solids and reducing sugars in the expressed sap all increased with the number of leaves allowed to remain on the plants. In general, the differences between treatments were most marked among the lower trusses. Statistical analysis of the results shows that the values for treatment E, in which two extra leaves were allowed to develop below each truss, were significantly higher than those for the control plants (treatment D). In contrast, removing all the leaves except those immediately below each truss (treatment A) markedly affected fruit composition, the content of dry matter and sugars in the fruit, and the concentrations of sugars and total solids in the expressed sap, all being significantly lower for treatment A than for the remaining treatments. The contrast between treatments B, C and D was less pronounced, but in general, differences between treatments B and D were significant at the 1% probability level. In marked contrast to the other analytical results, the values obtained for titratable acidity of the expressed sap of fruit from the various treatments were not significantly different.

TABLE I

PERCENTAGE DRY MATTER IN THE FRUIT FROM TREATMENTS A—E
(SERIES I)

Truss	Treatment					Mean
	A	B	C	D	E	
1	5.92	6.81	7.15	7.28	7.91	7.01
2	6.84	7.46	7.62	7.95	8.30	7.63
3	5.30	6.03	6.17	6.34	6.86	6.14
4	5.21	5.54	5.63	5.70	5.99	5.61
5	4.94	5.17	5.50	5.51	5.85	5.39
6	5.36	5.48	5.63	5.73	6.09	5.66
7	5.20	5.37	5.82	5.80	6.26	5.69
8	5.24	5.44	5.22	5.31	5.14	5.27
9	5.15	5.30	5.20	5.51	5.30	5.29
10	4.93	5.17	5.14	5.16	5.42	5.16
Mean	5.41	5.78	5.91	6.03	6.31	

Significant differences at $P=0.05$: treatments 0.23; trusses 0.32

„ „ „ $P=0.01$: „ 0.40; „ 0.57

TABLE II

TOTAL REDUCING SUGARS EXTRACTED BY HOT WATER IN FRUIT FROM
TREATMENTS A—E (SERIES I)

Truss	Treatment					Mean
	A	B	C	D	E	
1	% 3.06	% 3.51	% 3.88	% 3.62	% 4.16	% 3.65
2	2.86	3.44	3.86	3.81	4.33	3.66
3	2.96	3.37	3.63	3.84	4.05	3.57
4	2.99	3.00	3.27	3.09	3.48	3.17
5	2.82	3.04	3.29	3.42	3.59	3.23
6	2.92	2.80	3.16	3.31	3.27	3.09
7	2.97	3.09	3.34	3.40	3.58	3.28
8	3.22	2.19	2.26	3.51	3.51	3.36
9	3.12	3.09	3.07	3.39	3.46	3.23
10	2.47	2.81	—	2.67	3.15	2.78
Mean	2.94	3.13	3.43	3.41	3.66	

Significant differences at $P=0.05$: treatments 0.14; trusses 0.22

„ „ „ $P=0.01$: „ 0.25; „ 0.39

TABLE III

TOTAL SOLIDS (g./100 ml.) IN THE EXPRESSED SAP OF FRUIT FROM
TREATMENTS A—E (SERIES I)

Truss	Treatment					Mean
	A	B	C	D	E	
1	4.26	4.79	5.11	5.20	5.50	4.97
2	4.53	4.77	5.22	5.35	5.66	5.11
3	3.86	4.46	4.52	4.86	5.34	4.61
4	4.04	4.25	4.37	4.68	4.86	4.44
5	3.89	4.11	4.40	4.53	4.70	4.33
6	3.84	3.91	4.15	4.06	4.24	4.04
7	3.86	3.50	3.73	4.06	3.98	3.83
8	3.58	3.63	3.77	3.93	4.05	3.79
9	4.02	3.88	3.81	4.19	4.23	4.03
10	3.73	4.06	4.03	4.03	4.22	4.02
Mean	3.96	4.14	4.31	4.49	4.68	

Significant differences at $P=0.05$: treatments 0.17; trusses 0.24

„ „ „ $P=0.01$: „ 0.30; „ 0.43

TABLE IV

REDUCING SUGARS (g./100 ml.) IN THE EXPRESSED SAP OF FRUIT
FROM TREATMENTS A—E (SERIES I)

Truss	Treatment					Mean
	A	B	C	D	E	
1	3.23	3.76	4.22	4.17	4.52	3.98
2	3.31	3.66	4.12	4.09	4.53	3.94
3	2.88	3.43	3.58	3.89	4.37	3.63
4	3.05	3.30	3.34	3.61	3.74	3.41
5	2.94	3.27	3.56	3.51	3.73	3.40
6	3.05	3.16	3.44	3.34	3.46	3.29
7	2.99	3.05	3.29	3.55	3.44	3.26
8	2.85	2.92	3.01	3.14	3.09	3.00
9	3.12	3.09	3.07	3.39	3.46	3.23
10	2.96	3.30	3.36	3.41	3.56	3.32
Mean	3.04	3.29	3.50	3.61	3.79	

Significant differences at $P=0.05$: treatments 0.16; trusses 0.23

„ „ „ $P=0.01$: „ 0.23; „ 0.40

TABLE V

TITRATABLE ACIDITY (ml. N/10 sodium hydroxide per 10 ml.) of
SAP EXPRESSED FROM FRUIT FROM TREATMENTS A—E (SERIES I)

Truss	Treatment					Mean
	A	B	C	D	E	
1	6.0	6.2	6.4	6.4	6.9	6.4
2	6.1	5.4	5.2	6.2	6.0	5.8
3	5.7	6.1	6.1	6.5	6.5	6.2
4	5.1	5.0	5.0	5.1	5.2	5.1
5	4.5	4.3	4.5	5.0	4.7	4.6
6	4.6	4.4	3.8	4.8	5.0	4.5
7	4.3	5.1	4.0	4.4	4.5	4.5
8	3.5	3.5	3.7	3.5	3.3	3.5
9	4.1	3.1	3.4	3.2	2.9	3.3
10	3.7	3.0	2.9	3.1	3.1	3.2
Mean	4.8	4.6	4.5	4.8	4.8	

Significant differences at $P=0.05$: trusses 0.4

„ „ „ $P=0.01$: „ 0.8

It will also be seen from Tables I – V that the concentrations of all the constituents studied decreased from the lower to the higher trusses. The decline in acidity of the expressed sap was particularly marked, values for the higher trusses being amongst the lowest ever encountered in the course of our investigations. It is not yet known whether this effect is due to position on the plant or to seasonal trends.

The effect of the different treatments on fruit yield is shown in Table VI, in which the mean yields per plant are given for each treatment up to and including the second, fourth, sixth, eighth and tenth trusses. Throughout the life of the plants treatment A resulted in lower yields than the other treatments, while treatment E produced the highest yields. The lower value shown for the tenth truss of treatment E is explained by an outbreak of *Botrytis* which proved difficult to control and necessitated the removal of several ninth and tenth trusses before the fruit had fully developed. Statistical analysis of the total yield data (i.e., to the tenth truss) shows that the yield produced by treatment A was significantly lower than the other treatments, but no significant differences were found in the yields from treatments B – E. Statistical analysis of the data for mean fruit weight, subdivided on the basis of individual trusses, also shows significant differences both between treatments and truss positions. Thus fruit from treatment A was significantly lighter than from the other treatments, and mean fruit size decreased in the later stages of cropping.

The effect of the treatments (Series I) on fruit quality is shown in Table VII. It will be seen that fruit quality was, in general, very poor, irrespective of the treatment; approximately half of the total yield consisted of blotchy fruit. There is some indication, however, that treatment A slightly improved fruit quality, the percentage of blotchy fruit being lower, and the proportion of grades A and B being slightly higher, than for the other treatments.

Series II

The various treatments used in Series I were, with the exception of treatment A, comparatively mild; in Series II the effect on fruit composition of more severe defoliation was studied. The treatments were as follows:—

- F. Leaves were progressively removed from the plants so as to maintain six fully expanded leaves at the top of the main stem.
- G. As in treatment F, except that nine fully expanded leaves were retained at the top of the main stem.
- H. All leaves allowed to remain on the main stem.

TABLE VI

MEAN YIELD OF PLANTS FROM TREATMENTS A—E (SERIES I) UP TO AND INCLUDING THE SECOND, FOURTH, SIXTH, EIGHTH AND TENTH TRUSSES

Treatment	Mean yield per plant					Mean fruit weight
	To second truss	To fourth truss	To sixth truss	To eighth truss	To* tenth truss	
A	g. 1,556	g. 3,144	g. 4,724	g. 5,945	g. 6,844	g. 88.7
B	1,739	3,771	5,759	7,491	8,462	96.0
C	1,948	3,994	6,090	7,691	8,715	95.8
D	1,800	3,718	5,918	7,865	9,088	98.5
E	2,292	4,639	6,621	7,962	8,742	97.0

* Significant difference at $P=0.05$: 551

„ „ „ $P=0.01$: 858

TABLE VII

VISUAL GRADING OF FRUIT FROM TREATMENTS
A—E (SERIES I)

Treatment	Grade			
	A+B	C	D	Green
	%	%	%	%
A	7.5	73.8	4.6	14.1
B	5.5	77.1	4.8	12.6
C	5.3	80.3	3.4	11.0
D	4.2	81.4	4.6	9.8
E	6.7	77.6	3.1	12.6

Nine blocks of three tomato plants (variety "Potentate"), each block containing one plant of each treatment, were randomised in three rows along the glasshouse staging, with guard plants at the east and west ends. The defoliation treatments were commenced at the end of April and continued until the end of June. Only six trusses were allowed to develop, after which the plants were stopped.

The results for the dry matter content of the fruit and the total reducing sugars extracted by hot water are shown in Tables VIII and IX. Data for total sap solids, reducing sugars and the titratable acidity of the expressed sap are shown in Tables X, XI, and XII respectively. Fruit from the first four trusses only were analysed. As will be seen later, treatments F and G reduced yields markedly, and after the second truss insufficient fruit was ripe at any one time to justify sampling.

TABLE VIII

PERCENTAGE DRY MATTER IN THE FRUIT FROM
TREATMENTS F—H (SERIES II)

Truss	Treatment			Mean treatments G & H
	F	G	H	
1	4.52	4.87	5.73	5.30
2	4.94	4.81	5.56	5.18
3	—	4.94	5.55	5.25
4	—	4.68	5.53	5.11
Mean	—	4.83	5.47	

Significant difference between means of treatments G & H at $P=0.05$: 0.18

„ „ „ „ „ „ „ $P=0.01$: 0.33

TABLE IX

TOTAL REDUCING SUGARS EXTRACTED BY HOT
WATER IN FRUIT FROM TREATMENTS F—H (SERIES II)

Truss	Treatment			Mean treatments G & H
	F	G	H	
1	% 2.11	% 2.22	% 3.02	% 2.62
2	2.08	2.57	2.65	2.61
3	—	2.20	2.69	2.45
4	—	2.42	3.57	3.00
Mean	—	2.35	2.98	

TABLE X

TOTAL SOLIDS (g./100 ml.) IN THE EXPRESSED
SAP OF FRUIT FROM TREATMENTS F—H (SERIES II)

Truss	Treatment			Mean treatments G & H
	F	G	H	
1	3.54	3.46	4.56	4.01
2	3.35	3.25	3.90	3.58
3	—	3.39	4.21	3.75
4	—	3.38	4.24	3.81
Mean	—	3.35	4.23	

Significant difference between means of treatments G & H at $P=0.05$: 0.30

„ „ „ „ „ „ „ $P=0.01$: 0.54

TABLE XI

REDUCING SUGARS (g./100 ml.) IN THE EXPRESSED
SAP OF FRUIT FROM TREATMENTS F—H (SERIES II)

Truss	Treatment			Mean treatments G & H
	F	G	H	
1	2.23	2.28	3.18	2.73
2	2.20	2.27	3.06	2.67
3	—	2.32	(3.17*)	2.75
4	—	2.42	3.29	2.86
Mean	—	2.32	3.18	

Significant difference between means of treatments G & H at $P=0.05$: 0.20

„ „ „ „ „ „ „ $P=0.01$: 0.28

* Calculated "missing value"

TABLE XII

TITRATABLE ACIDITY (ml. N/10 sodium hydroxide
per 10 ml.) OF EXPRESSED SAP OF FRUIT FROM
TREATMENTS F—H (SERIES II)

Truss	Treatment			Mean treatments G & H
	F	G	H	
1	7.2	6.7	6.9	6.8
2	7.0	5.7	5.7	5.7
3	—	6.2	4.9	5.6
4	—	5.6	4.2	4.9
Mean	—	6.1	5.4	

The dry matter content of the fruit, the total reducing sugars extracted by hot water, and the sap solids and reducing sugars in the expressed sap, all increased with the number of leaves allowed to remain on the plants. The differences between the means for treatments G and H were statistically significant, with the exception of the values for sugars extracted by hot water. In contrast to Series I, however, the differences between the means for the trusses were not statistically significant. The titratable acidity of the expressed sap was, in general, higher the more severe the defoliation, but the results for the various treatments are not significantly different. First truss fruit were again more acid than those from later trusses.

The marked effect of treatments F and G on the mean yield per plant and on the mean fruit weight are shown in Table XIII. The yield of plants from treatment F was less than 30% of that of the control plants, and the fruit size was also markedly reduced ($P = 0.01$). The mean yield of plants from treatment G was both significantly higher than that from treatment F and significantly lower than that from the control plants (treatment H).

TABLE XIII

MEAN YIELD OF PLANTS FROM TREATMENTS F—H
(SERIES II), AND MEAN FRUIT WEIGHT

Treatment	Mean yield per plant*	Mean fruit weight
F	g. 1,794	g. 64.4
G	3,142	81.3
H	5,696	98.4

* Significant difference at $P=0.001$: 778

The effect of the treatments on fruit quality is shown in Table XIV. A higher percentage of good quality fruit was produced by plants from treatment F than from the control plants, while at the same time the percentage of grade C fruit was lower. The percentages of fruit from the plants in Series II which were graded in the sub-grades C1, C2 and C4 as previously defined are shown in Table XV. The percentage of fruit with severe blotchy ripening (C2) was markedly reduced by treatment F and to a lesser extent by treatment G. At the same time the proportion of fruit in grade C4 was increased.

TABLE XIV

VISUAL GRADING OF FRUIT FROM TREATMENTS
F—H (SERIES II)

Treatment	Grade			Green
	A+B	C	D	
F	% 22.7	% 52.4	% 9.7	% 15.2
G	14.2	62.6	14.3	8.9
H	5.4	74.3	6.0	14.3

TABLE XV

SUB-CLASSIFICATION OF THE IRREGULARLY
COLOURED FRUIT (GRADE C) FROM TREATMENTS
F—H (SERIES II)

Treatment	Grade		
	C1*	C2*	C4*
F	19.24	13.47	11.00
G	24.03	29.51	3.10
H	21.18	49.18	1.25

* For definitions see text

Series III

Tomato plants of variety "L.M.R. 1" were used in this part of the investigation, there being only two treatments as follows:—

J. All leaves on the main stem retained.

K. The first leaf above soil level retained and every alternate leaf above removed as the plants grew. At any one time of leafing, leaves were only removed up to the last truss on which fruit had set.

Ten blocks, each of two plants, were randomised in a single line along the glasshouse staging with guard plants at each end. The treatments were begun at the end of March and continued until the middle of June. The growing point was removed after three leaves had expanded above the tenth truss.

The results for dry matter content, total reducing sugars extracted by hot water, and total solids, reducing sugars and titratable acidity in the expressed sap are shown in Tables XVI, XVII, XVIII, XIX and XX respectively. Once again the dry matter content, total reducing sugars extracted by hot water, and the concentrations of sap solids and sugars in the sap, were all significantly lower in fruit from the defoliated plants (treatment K) than in those from the control plants (treatment J). The titratable acidity of the sap was lower in fruit from treatment K than in treatment J but the difference is not statistically significant.

TABLE XVI
PERCENTAGE DRY MATTER IN THE FRUIT FROM
TREATMENTS J AND K (SERIES III)

Trusses	Treatment		Mean
	J	K	
1 & 2	7.19	6.05	6.62
3 & 4	8.50	6.59	7.55
5 & 6	7.57	5.98	6.78
7 & 8	6.59	5.54	6.07
9 & 10	6.84	5.93	6.39
Mean	7.23	6.01	

Significant differences at $P=0.05$: treatments 0.52; trusses 0.82
 „ „ $P=0.01$: treatments 0.86; trusses 1.36

TABLE XVII
TOTAL REDUCING SUGARS EXTRACTED BY HOT WATER
IN FRUIT FROM TREATMENTS J AND K (SERIES III)

Trusses	Treatment		Mean
	J	K	
1 & 2	% 3.88	% 3.38	% 3.63
3 & 4	4.88	3.44	4.16
5 & 6	4.01	3.23	3.62
7 & 8	3.50	2.87	3.19
9 & 10	4.12	3.38	3.75
Mean	4.08	3.26	

Significant difference between treatment means at $P=0.05$: 0.45
 „ „ „ „ „ „ $P=0.01$: 0.75

TABLE XVIII

TOTAL SOLIDS (g./100 ml.) IN THE EXPRESSED SAP
OF FRUIT FROM TREATMENTS J AND K (SERIES III)

Trusses	Treatment		Mean
	J	K	
1 & 2	6.00	4.68	5.34
3 & 4	6.69	4.95	5.82
5 & 6	5.78	4.36	5.07
7 & 8	4.75	3.87	4.31
9 & 10	5.42	4.43	4.93
Mean	5.69	4.50	

Significant differences at $P=0.05$: treatments 0.43; trusses 0.68

„ „ „ $P=0.01$: „ 0.71 „ 1.13

TABLE XIX

REDUCING SUGARS (g./100 ml.) IN THE EXPRESSED
SAP OF FRUIT FROM TREATMENTS J AND K (SERIES III)

Trusses	Treatment		Mean
	J	K	
1 & 2	4.45	3.35	3.90
3 & 4	4.95	3.69	4.32
5 & 6	4.29	3.29	3.79
7 & 8	3.41	3.02	3.22
9 & 10	4.31	3.48	3.90
Mean	4.22	3.34	

Significant difference at $P=0.05$: treatments 0.42

„ „ „ $P=0.01$: „ 0.69

TABLE XX

TITRATABLE ACIDITY (ml. N/10 sodium hydroxide
per 10 ml.) OF THE EXPRESSED SAP OF FRUIT
FROM TREATMENTS J AND K (SERIES III)

Trusses	Treatment		Mean
	J	K	
1 & 2	9.4	8.6	9.0
3 & 4	9.9	8.3	9.1
5 & 6	8.0	6.3	7.2
7 & 8	5.6	5.4	5.5
9 & 10	3.3	3.2	3.3
Mean	7.2	6.4	

Significant differences at $P=0.05$: trusses 1.5

„ „ „ $P=0.01$: „ 2.4

As in Series I, fruit from the earlier trusses tended to have a higher content of dry matter and a higher concentration of soluble solids in the expressed sap. No significant differences were found between trusses with regard to either total or sap soluble sugars, but there was a marked decrease in the titratable acidity of fruit from the later trusses.

The effects of treatments J and K on the mean yield per plant, and on the average weights of individual fruits, are shown in Table XXI. In contrast to the results for Series I and II (Variety "Potentate") the mean yield and fruit weight were increased slightly by the defoliation treatment. Statistical analysis shows, however, that the differences are not significant.

TABLE XXI
MEAN YIELD PER PLANT AND AVERAGE FRUIT
WEIGHT FROM TREATMENTS J AND K (SERIES III)

Treatment	Mean yield per plant	Average fruit weight
J	^{g.} 6,130	^{g.} 64.8
K	6,634	70.7

The effects on fruit quality are shown in Table XXII. Fruit from variety "L.M.R. 1" is often characterised by deep green shading around the calyx with no other apparent defect (grade C4), and accordingly this grade has been included with grades A and B. Removal of every alternate leaf (Treatment K) resulted in a slight decrease in fruit of grade C and in a concomitant increase in the top quality fruit, but the differences are relatively small.

TABLE XXII
VISUAL GRADING OF FRUIT FROM TREATMENTS
J AND K (SERIES III)

Treatment	Grade			Green
	A+B+C4	C*	D	
J	% 42.5	% 41.1	% 1.3	% 15.2
K	45.9	38.1	2.0	13.9

* Excluding Grade C4

Discussion

It is clear from the foregoing results that the partial defoliation of tomato plants can profoundly affect many aspects of fruit composition. The dry matter content, the reducing sugars extracted by hot water, and the concentrations of sap solids and sugars in the sap of two varieties, "Potentate" and "L.M.R. 1", were all progressively decreased by increasing defoliation. Additional data for total sugars soluble in 80% aqueous ethanol and for alcohol-insoluble solids, omitted from this report, show a similar trend. On the other hand, allowing two extra leaves to develop on an axillary shoot immediately below each truss (treatment E, Series I) was accompanied by a significant increase in all these fruit constituents. In contrast to sugars and total solids, the effect of defoliation on the titratable acidity of the fruit was far less marked, and differing results were obtained among the three series of treatments.

Hoffman (4) has shown that removal of leaves below the bottom truss reduced yields of tomato plants growing outdoors, the reduction being further accentuated by the removal of leaves from between the first and second trusses. Work in New Zealand (1) has also shown that early removal of laterals from the lower part of the stem reduced yields but improved the quality of glasshouse tomatoes. In the present investigation, although fruit composition was markedly affected by the removal of about 30% or more of the leaves, fruit yield was not significantly decreased until more than 50% of the leaves had been removed (treatment A, Series I; treatments F and G, Series II). With the variety "L.M.R. 1" removal of every alternate leaf even resulted in a slightly increased mean yield per plant, but the difference was not statistically significant.

Hemphill and Murneek (3) allowed the axillary shoots to develop, stopping them after two leaves had been produced. They found that this treatment increased the yield and size of glasshouse tomatoes, one axillary shoot below a truss giving nearly as high an increase as two shoots. Kerr (5), however, repeated this experiment using 39 different tomato varieties, and found no effect on total yield. He concluded that extra foliage was not desirable under the conditions prevailing in Ontario. Use of this treatment in the present investigation (treatment E, Series I) had no significant effect on yield, although the dry matter and sugar content of the fruit was increased thereby.

It will be seen from the results reported here that there was a general tendency for the various fruit constituents studied to decrease in concentration with each successive truss, the first and second trusses being the highest. American work (2) has shown that the titratable acidity, reducing sugars and total pectic substances decreased with each successive harvest during the autumn crop, and increased with each successive harvest during the spring crop, the fruit in this latter instance being picked between the 24th April and the 2nd July. The correlation between the concentrations of fruit constituents and the hours of sunshine in the period in which the fruits made the major portion of their growth was highly significant, and the authors suggest that light is one of the major limiting factors in fruit composition. Calculations are being made in order to determine whether the same relation holds in the case of the present results.

Tables VII, XV and XXII show that there was some effect of the various defoliation treatments on the visual grading of the fruit. Reducing the number of leaves resulted in better quality fruit, the two most drastic defoliation treatments F and G being the most effective in this respect. Any such improvement was, however, brought about at the expense of a marked reduction in yield.

Symptoms of magnesium deficiency appeared among the plants of Series I. Not all treatments were affected to the same degree, however. Plants of treatments C, D and E all showed marked symptoms, whereas those from treatments A and B which were more severely defoliated showed either no indication of magnesium deficiency or only a slight chlorosis. It seems likely that the amount of magnesium available was adequate for the defoliated plants where the total leaf area was considerably reduced, but insufficient for plants with more than double the leaf area. Further work is being undertaken in this connection.

Conclusions

1. In three series of experiments removal of foliage markedly decreased the sugar and dry matter content of the fruit, and reduced the concentration of sugars and total solids in the expressed sap.

2. Retention of lateral shoots increased the content of sugars and total dry matter in the fruit (Series I).

3. The titratable acidity of the expressed fruit juices was not significantly affected by the treatments, and differing results were obtained in the three sets of trials.

4. Removal of foliage lowered the yields of fruit from variety "Potentate".

5. Severe defoliation (Series II) reduced the proportion of irregularly coloured fruit, and also affected the detailed classification of the latter grade.

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3. CHROMATOGRAPHIC STUDIES OF THE FREE SUGARS OF TOMATO FRUIT

by

J. N. DAVIES

Quantitative determination of the individual free sugars in tomato fruit by means of chromatographic techniques referred to in the last Report (1) has been examined further. Some difficulty was experienced initially in obtaining on paper chromatograms sufficient separation of glucose and fructose to permit their quantitative determination. Excellent separation of these sugars has now been achieved by double development of paper chromatograms with a solvent mixture consisting of ethyl acetate, acetic acid and water (9:2:2, v/v). After elution from the paper with distilled water, the sugars have been determined colorimetrically (2, 3). Amounts of glucose and fructose in the range 50—200 μ g have been satisfactorily determined by this means. Known amounts of the sugars applied to papers, developed and extracted, have given recoveries within 5% of the theoretical.

Using this technique, glucose and fructose have been estimated in ethanolic extracts of tomato fruit. Some initial results for ten different tomato varieties sampled in 1956 are shown in Table I.

TABLE I
GLUCOSE AND FRUCTOSE IN RIPE FRUIT OF TEN TOMATO VARIETIES,
TOGETHER WITH THE GLUCOSE/FRUCTOSE RATIO

Tomato variety	Glucose	Fructose	Glucose/ fructose ratio	Total glucose + fructose	Total reducing sugars*
	%	%		%	%
L.M.R. 1	1.51	1.58	0.96	3.09	3.07
Radio	1.16	1.35	0.86	2.51	2.52
E.S. 5	1.13	1.34	0.84	2.47	2.57
Delicious	1.78	1.77	1.01	3.55	3.45
Down's Seedling	1.03	1.16	0.89	2.19	2.37
Wheatleys	1.13	1.21	0.93	2.34	2.70
Ailsa Craig	1.29	1.53	0.84	2.82	2.72
E.S. 1	1.31	1.53	0.86	2.84	2.80
Potential	1.43	1.63	0.88	3.06	3.07
Potentate	1.49	1.63	0.91	3.12	3.02

Note:—All results are expressed as percentages of fresh weight

* Determined by the macro-method of Roy & Hughes (4)

In general, more fructose than glucose was present in the fruit samples, the glucose/fructose ratios with one exception being less than unity. No trace of sucrose could be detected on any of the chromatograms. In addition to the quantitative determination of the individual sugars, the total reducing sugars in the extracts were estimated by the volumetric macro-method (4) used in all previous studies of fruit composition carried out in the Chemistry Department. These results, shown in the last column of Table I, are numerically similar to the sum of glucose and fructose as determined by the chromatographic method and shown in the penultimate column. Statistical analysis of the data shows that the two sets of results are not significantly different.

Quantitative studies of glucose and fructose in tomato fruit at various stages of ripeness, and in normal, "blotchy" and "waxy" fruit are in progress.

Traces of a sugar indistinguishable chromatographically from sucrose have been found in one or two samples of ripe tomato fruit, but in general, sucrose appears to be either absent or below the threshold of detection. Williams & Bevenue (6) have reported a trace of sucrose in ripe tomato fruit and Smith (5) has reported concentrations of up to about 1.5% of the fresh weight. Attempts to detect sucrose in freshly picked fruit under experimental conditions designed to minimise any possible inversion of the sucrose during the preparation of the extract have so far met with no success. Further investigations are in progress.

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4. GLASSHOUSE CALIBRATION TRIALS; SOIL ANALYSES IN RELATION TO TOMATO YIELDS

by

G. W. WINSOR & J. N. DAVIES

An extensive programme of soil and tissue analyses, arising from the calibration of two blocks of trial glasshouses, B1-4 & C1-4, has been continued. In 1955 these glasshouses were again treated with stable manure at the rate of 20 tons per acre, but no fertilizers were applied. Analytical data for soil samples taken at the end of the cropping season in 1954, and for samples of tomato foliage taken in 1955, have already been presented in previous reports (1, 2).

In the present report is presented a summary of the analytical results for soil samples taken in September 1955, analyses of which were completed early in 1957.

Sampling and analysis

The numbering and layout of the plots in each house have been described previously (1, 2). Each soil sample consisted of seven borings made with an auger to a depth of nine inches. Details of the analytical methods used are given in the earlier report (1).

Results

The full data for the 448 plots are too extensive to be reported here, and still await detailed statistical analysis. The range of values for each house, and for all eight houses combined, are given in Table I; the corresponding mean values are shown in Table II, and the coefficients of variation in Table III.

TABLE I
RANGE OF ANALYTICAL VALUES FOR SOIL SAMPLES FROM HOUSES
B1-4, C1-4 AT THE END OF 1955 CROPPING SEASON

House	pH	pC	Available* P ₂ O ₅ (%)	Available* K ₂ O (%)	Organic Carbon (%)
B1	6.80—8.18	3.65—4.09	0.0009—0.0033	0.0035—0.0092	0.94—1.33
B2	5.22—8.03	3.35—4.24	0.0012—0.0034	0.0039—0.0077	0.96—1.31
B3	6.59—7.94	3.61—4.03	0.0009—0.0027	0.0042—0.0072	0.96—1.55
B4	6.72—7.86	3.70—3.97	0.0008—0.0033	0.0039—0.0092	0.92—1.55
C1	6.57—7.73	3.71—4.15	0.0004—0.0027	0.0047—0.0082	0.82—1.60
C2	6.63—8.13	3.73—4.19	0.0005—0.0025	0.0034—0.0079	0.79—1.11
C3	6.84—8.02	3.72—4.19	0.0005—0.0027	0.0039—0.0084	0.81—1.12
C4	7.14—7.96	3.56—4.20	0.0007—0.0023	0.0052—0.0089	0.87—1.15
B1—C4	5.22—8.18	3.35—4.20	0.0004—0.0034	0.0034—0.0092	0.79—1.60

* Soluble in 0.5N-acetic acid

Previous surveys have shown considerable variability in the values for pH; the wide range of values is again apparent (Table I). The mean values for each house are all higher than those of 1954, although the range is wider. The values for pC are, in general, slightly lower than those found in the 1954 samples, but the concentration of soluble salts in the soil still remains very low. Values for "available" phosphate and potash are again very low throughout. Mean values for phosphate are, in general, slightly higher than those found in the previous year's samples, presumably as a result of the application of stable manure. The values for potash, on the other hand, are all

considerably lower than those found in 1954. The content of organic matter in the soil remains low throughout; the results indicate a slight increase in B Block but a decrease in C Block as compared with the previous year.

The coefficients of variation (Table III) are of a similar order of magnitude to those obtained in 1954, and again show the greatest variability in the phosphate content of the soils. Arising out of this work, alternative methods for the assessment of "available" phosphate have been examined, and studies of the response of tomato plants to added phosphate have been made in soils of low phosphate status. The results will be given in a subsequent report, but it may be noted that the levels of phosphate in Blocks B and C are definitely below optimum for the early stages of growth of tomato plants.

Correlations between crop yield and soil analysis

Full crop data for the 448 plots were obtained by the crop recorders. The range of values, together with the means for each house, are given in Table IV. Correlation coefficients relating crop yield and the analytical data are shown in Table V.

TABLE II
MEAN ANALYTICAL VALUES FOR SOIL SAMPLES FROM HOUSES B1—4,
C1—4 AT THE END OF THE 1955 CROPPING SEASON

House	pH	pC	Available* P ₂ O ₅ (%)	Available* K ₂ O (%)	Organic carbon (%)
B1	7.41	3.86	0.0018	0.0052	1.08
B2	7.19	4.00	0.0018	0.0054	1.10
B3	7.20	3.86	0.0017	0.0054	1.09
B4	7.28	3.85	0.0018	0.0059	1.10
C1	7.22	3.94	0.0013	0.0057	1.02
C2	7.20	3.93	0.0011	0.0049	0.94
C3	7.53	3.97	0.0011	0.0061	0.96
C4	7.62	3.91	0.0013	0.0066	1.02
B1—C4	7.33	3.91	0.0015	0.0056	1.04

* Soluble in 0.5N-acetic acid

TABLE III
COEFFICIENTS OF VARIATION FOR HOUSES B1—4, C1—4

House	pH	pC	Available* P ₂ O ₅	Available* K ₂ O	Organic carbon
B1	4.8	3.2	28.2	18.7	6.0
B2	6.4	4.1	27.8	18.6	6.1
B3	4.7	2.6	24.6	13.0	8.8
B4	3.7	1.7	27.9	19.8	9.1
C1	3.7	2.6	35.6	13.4	11.4
C2	4.7	2.4	52.2	17.2	7.8
C3	3.0	3.3	43.5	19.3	7.5
C4	2.5	2.6	29.3	13.6	6.3

* Soluble in 0.5N-acetic acid

Of the 32 correlation coefficients given for individual houses in Table V, twelve indicate a positive relationship between yield and soil analyses significant at $P = 0.05$ or better; in eight of the twelve the results confirm relationships established during the previous season (1), including positive relationships between yield and soil pH in houses C1, C2, and C3, yield and soil phosphate in houses B4, C1 and C2, and yield and organic carbon in houses C1 and C2.

TABLE IV
SUMMARY OF CROP DATA FOR B AND C BLOCKS
DURING 1955, EXPRESSED IN LB. PER PLANT

House	Range	Mean
B1	6.9—11.8	9.0
B2	6.8—11.1	8.2
B3	7.1— 9.7	8.3
B4	6.7—11.4	8.6
C1	5.6—10.3	7.5
C2	4.3— 8.6	6.1
C3	4.9— 9.0	7.2
C4	5.4—11.0	6.8
B1—C4	4.3—11.8	7.7

TABLE V
CORRELATION COEFFICIENTS RELATING CROP YIELD AND
SOIL ANALYSES

House	No. of plots	pH	Available P_2O_5 (%)	Available K_2O (%)	Organic Carbon (%)
B1	56	0.001	0.002	0.004	0.169
B2	56	0.123	0.343**	0.002	—0.183
B3	56	—0.144	0.146	—0.104	0.096
B4	56	—0.185	0.320*	—0.262	0.267*
C1	56	0.276*	0.325*	—0.016	0.319*
C2	56	0.530***	0.550***	0.273*	0.542***
C3	56	0.300*	0.139	0.065	0.618***
C4	56	—0.134	0.158	—0.057	—0.155
B1—B4	224	0.050	0.200**	—0.091	0.074
C1—C4	224	0.548***	0.292***	0.199**	0.316***
B1—C4	448	0.295***	0.489***	—0.051	0.317***

* $P=0.05$ ** $P=0.01$ *** $P=0.001$

As in 1954, correlations between yield and soil analyses were more numerous in C Block than in B Block. Nine of the twelve significant correlations found within individual houses occurred in houses C1–3, whereas three houses (B1, B3 and C4) failed to show any relationship at all between yield and soil analysis; two of the latter three houses had also failed to show any significant correlation in the previous season.

The results for B Block and for C Block, each taken as a whole, show significant correlations between yield and pH, phosphate, potash and organic carbon in C Block, but only with soil phosphate in B Block. On combining the data for all 448 plots no significant relationship was found between yield and "available" potash in the soil, in contrast to the result in 1954, when the levels of soil potash were somewhat higher.

Discussion of results

The levels of "available" phosphate and potash in the soils of B and C Blocks during both 1954 and 1955 may be regarded as below the requirements of the crop. Analyses of leaf samples taken during 1955 not only confirmed the low availability of potash, but also showed that the amounts of nitrogen available to the plants were inadequate. Thus at least three major plant nutrients were present at levels below the optimum, and it is hardly surprising that correlations between yields and the levels of any one element were not in every case significant.

An interesting feature of the analytical results for soils and foliage (2) during 1955 is that, whereas the tissue analyses showed significant positive correlations between potash and yield in five out of eight houses, only in one house (C2) was there any correlation with "available" potash in the soil. On the other hand, significant positive correlations between crop yields and soil phosphate were found for four houses during 1955 (five houses in 1954), but only in one house was a significant positive correlation found between yield and phosphorus content of the foliage; in four houses the correlation with phosphate in the tissue was in fact a significant negative one.

Considerable caution is thus required in assessing the analytical results obtained. Although some further work, both statistical and experimental, still remains to be done, the present position with regard to crop growth in these calibration trials may be summarized as follows:—

1. Phosphate deficiency was a limiting factor in the early growth of tomato plants in these houses, as shown by visual symptoms and confirmed by subsidiary trials with pot-grown plants.
2. Later in the season symptoms of nitrogen deficiency developed, as confirmed by tissue analysis.
3. The extremely low levels of potassium found both in soil and plant analyses, together with significant correlations between yields and potash content of the foliage, indicate a deficiency of this element; visual symptoms were considerably masked by the occurrence of other deficiencies.

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5. UREA-FORMALDEHYDE COMPOUNDS AS SLOW-ACTING NITROGENOUS FERTILIZERS

by

M. I. E. LONG & G. W. WINSOR

Growth of tomato plants in potting mixtures containing urea-formaldehyde compounds

In the Annual Report for 1956 the results of glasshouse trials were reported in which certain urea-formaldehyde compounds were tested as slow-acting nitrogenous fertilizers for tomato plants grown in pots. These exploratory trials served to give preliminary information concerning the types of compound of possible value as slow-acting fertilizers, and to relate the results of soil incubation tests in the laboratory to those obtained in glasshouse trials. Of the five urea-formaldehyde compounds tested in 1956, one proved too rapid and three too slow to have any potential value as nitrogenous fertilizers, but the remaining compound (UFT. 5) showed promise.

During 1957 the glasshouse trials were continued with a further range of compounds, selected on the basis of earlier experience. Details of the various compounds are given in the next section.

Preparation of the urea-formaldehyde products.

UFT. 5. A methylene urea compound as prepared and used in the 1956 trials.

UFT. 6. A methylene ether compound of the type referred to in the 1956 Report and further discussed in a later section of the present report. Urea and formaldehyde were allowed to react at a molar ratio of urea to formaldehyde (U/F) of 0.67 in alkaline solution (2.5 g. potassium hydroxide per 100 g. urea); considerable heat was evolved during the early stages of reaction and a cooling system was necessary to keep down the temperature. After standing for 48 hours at 25°C., the mixture was neutralised and the solid product filtered off, washed with alcohol and dried. The yield was 74 g. per 100 g. of urea taken initially.

UFT. 7. A methylene urea compound prepared by a two-stage procedure. Urea (500 g.) was dissolved in sufficient formalin to give a U/F ratio of 0.5. The pH of the reaction mixture was adjusted to 9.0 in a borate buffer solution, and the temperature kept down to 25°C. by strong cooling until the evolution of heat diminished. After 24 hours the reaction mixture was warmed to 50°C. to bring more of the product into solution, and the supernatant liquid was decanted into 2 litres of a solution containing 500 g. per litre of urea. Any solid material remaining from the alkaline stage was dissolved in 500 ml. of water and added to the main batch. For the second stage of the reaction the pH was adjusted to 3.5 and the temperature maintained at 25°C. for 4 hours. The solid separating out was then filtered off and washed successively with water and alcohol before air-drying.

UFT. 8. Preparation similar to UFT. 7 except that the concentration of the urea solution for the second (acid) reaction stage was 750 g. per litre.

UFT. 9. Preparation similar to UFT. 7 and 8 but with a concentration of 1,000 g. urea per litre in the second (acid) reaction stage.

Analytical data for samples UFT. 5-9 are given in Table I. The methylene ureas (UFT. 5, 7, 8 and 9) all have a relatively high nitrogen content ranging from 37.4 to 40.6 % as compared with 27.3% nitrogen in the methylene ether type of compound. The solubilities of the compounds both in hot and cold water (5) are given in the Table, soluble nitrogen being expressed as a percentage of the total nitrogen content of the samples. Determinations of water-soluble nitrogen

have proved most useful in the course of these investigations, though it should be stressed that, owing to a tendency to hydrolysis in solution, the results should be regarded primarily as comparative values from a standardised procedure rather than as true solubilities in the strict sense of the term. Samples UFT. 8 and 9 both have relatively high solubilities for this type of compound (methylene urea), and the methylene ether showed a particularly marked increase in solubility in hot water. The total formaldehyde content of the samples was determined as previously described (4). For the methylene ureas the ratio of nitrogen to formaldehyde, corrected for free urea, was used to calculate the mean chain length of the compounds (1). The results for UFT. 7-9 show that the use of an increasingly large excess of urea in the second (acid) stage of the reaction resulted in decreased mean chain length, accompanied by increased solubility in water. Appreciable amounts of free urea were present in UFT. 8 and 9.

TABLE I
ANALYTICAL DATA FOR SOME UREA-FORMALDEHYDE COMPOUNDS
USED IN GLASSHOUSE TRIALS WITH TOMATO PLANTS

Sample	Total nitrogen	Water-soluble nitrogen		Free urea nitrogen*	Formaldehyde equivalent	Average chain length
		Cold	Hot			
	%	%	%	%	%	
UFT. 5	39.9	35.6	66.2	7.6	28.3	3.11
UFT. 6	27.3	19.2	92.1	3.9	49.3	—
UFT. 7	37.4	8.0	46.8	0.9	34.1	6.90
UFT. 8	38.3	70.4	92.9	13.9	26.7	3.23
UFT. 9	40.6	75.4	98.0	21.4	22.9	2.57

* Expressed as a percentage of the total nitrogen

Glasshouse trials with tomato plants

The five urea-formaldehyde products described in the preceding section were used as sources of nitrogen for tomato plants (variety "Potentate") grown in 10in. clay pots. The potting mixture consisted of loam, peat and grit, with phosphate and potash added at the J. I. P. 3 level. A total of 12 g. nitrogen was applied per pot for the whole season. In addition to the urea-formaldehyde compounds, treatments with hoof and horn were also included for comparison, with and without subsequent top-dressings of nitrogen. The full list of treatments was as follows:—

Treatment A. Hoof and horn, 2.5 g. nitrogen in the original potting mixture and 9.5 g. nitrogen in 12 equal top-dressings.

Treatment B. Hoof and horn, 12 g. nitrogen in the potting mixture and no top-dressings.

Treatment C. UFT. 5 }
D. UFT. 6 } 12 g. nitrogen in the potting mixture and no subsequent top-
E. UFT. 7 } dressings.
F. UFT. 8 }
G. UFT. 9 }

The plants for these experiments were all grown in the same compost (J.I.P. 1) in 3½in. pots until transferred to the various potting mixtures in 10in. pots on 2nd—3rd April. The pots were arranged on the centre bench of the glasshouse in eight randomised blocks, the experimental plants numbering 56 in all with additional plants as guard rows. All pots received top dressings of potash and phosphate, but no nitrogenous top-dressings were applied at any time except in treatment A.

One week after transfer to the 10in. pots the plants in treatments B (hoof and horn used entirely as base fertiliser) and G (UFT. 9, the methylene urea compound of shortest chain length and highest solubility) were very dark in colour and somewhat stunted, clearly showing the effects of excessive release of inorganic nitrogen from these fertilizers. In contrast, plants in treatment E (UFT. 7, the most insoluble of the methylene ureas tested) were pale in colour, indicating relatively slow release of nitrogen from the fertilizer.

Towards the end of the season the most obvious visual response was that plants receiving treatments B, E and G were nitrogen-deficient. In the case of treatment E (UFT. 7) this was clearly due to insufficiently rapid release of available nitrogen from the fertilizer to maintain good growth. In contrast, treatments B and G had shown very rapid release of inorganic nitrogen in the early stages of growth, much of which was doubtless lost by leaching, and were incapable of maintaining the supply of nitrogen later in the season.

With regard to the general development of the plants considerable difficulties were encountered, even among the best treatments, in maintaining strong healthy growth. Certain limitations on growth were, of course, inherent in the nature of the trials, including possible toxic effects of excess nitrogen from certain treatments in the early stages, and a deficiency of the same element in other cases. Very bright sunny weather, however, resulted in severe wilting and leaf scorch before adequate shading was available. Symptoms of magnesium deficiency were eliminated by spraying with magnesium sulphate, but iron and manganese deficiencies were also recognised, particularly where the treatment released insufficient nitrogen to mask the chlorosis; after spraying with solutions of iron and manganese salts no further signs of these deficiencies appeared in the later stages of growth, but it was considered that growth of the plants had been adversely affected meanwhile.

The total crop of fruit was recorded separately for each plant until August 29th, when the trial was discontinued. Yields of ripened fruit are given in Table II, and corresponding figures for total crop, including fruit picked green at the end of the experiment, are shown in Table III.

TABLE II
TOTAL CROP OF RIPENED TOMATO FRUIT FROM INDIVIDUAL PLANTS
GROWN IN 10IN. CLAY PLOTS

Treatment	Source of nitrogen	Block								Mean
		1	2	3	4	5	6	7	8	
A	Hoof and Horn*	<i>g.</i> 1,915	<i>g.</i> 2,841	<i>g.</i> 2,398	<i>g.</i> 2,518	<i>g.</i> 2,709	<i>g.</i> 2,308	<i>g.</i> 2,126	<i>g.</i> 2,193	<i>g.</i> 2,376
B	Hoof and Horn	1,885	1,908	2,054	1,920	1,584	2,112	1,838	1,847	1,894
C	UFT. 5	2,546	2,594	2,292	2,541	2,484	2,291	2,310	2,133	2,399
D	UFT. 6	2,091	2,166	2,330	1,985	2,021	1,965	2,243	1,810	2,076
E	UFT. 7	2,445	2,018	2,009	2,151	2,240	2,674	1,974	2,580	2,261
F	UFT. 8	2,102	2,175	2,010	2,080	2,598	2,132	2,636	2,228	2,245
G	UFT. 9	2,061	2,234	2,135	2,077	2,242	2,246	1,575	1,863	2,054
Mean		2,149	2,276	2,175	2,182	2,268	2,247	2,100	2,093	

* Top dressed

Note:—The experiment was discontinued at the end of August

Significant difference between treatment means: 234 g. at $P=0.05$; 313 g. at $P=0.01$

TABLE III

TOTAL CROP OF TOMATO FRUIT, INCLUDING FRUIT PICKED GREEN AT
THE END OF THE EXPERIMENT (29/8/57), FROM INDIVIDUAL PLANTS
GROWN IN 10in. CLAY POTS

Treatment	Source of nitrogen	Block								Mean
		1	2	3	4	5	6	7	8	
A	Hoof and Horn*	2,503	2,804	3,048	2,776	2,899	2,762	2,744	2,525	2,758
B	Hoof and Horn	2,055	2,224	2,140	2,058	1,962	2,152	2,182	1,937	2,089
C	UFT. 5	2,760	2,880	2,816	2,881	2,806	2,717	2,458	2,611	2,741
D	UFT. 6	2,549	2,796	2,758	2,707	2,257	2,497	2,655	2,364	2,573
E	UFT. 7	2,807	2,336	2,557	2,515	2,590	2,910	2,444	2,580	2,592
F	UFT. 8	2,398	2,463	2,420	2,428	2,654	2,374	2,708	2,836	2,535
G	UFT. 9	2,111	2,298	2,183	2,203	2,378	2,370	2,065	2,193	2,225
Mean		2,455	2,543	2,560	2,510	2,507	2,540	2,565	2,435	

* Top dressed

Significant difference between treatment means: 167 g. at $P=0.05$; 223 g. at $P=0.01$

Statistical analysis of the yield data shows highly significant differences among the treatment means, as indicated beneath the respective tables. The data for total crop in Table III are to be preferred, the trial being designed to test the ability of the various compounds to sustain growth, and the state of ripeness of the fruit at the end of the growth period, being, therefore, of secondary importance in this respect. From Table III the highest total yields were given, as might be expected, by hoof and horn applied in the customary manner both before planting and as top-dressings (treatment A), and by urea-formaldehyde sample UFT. 5, a methylene urea product. As emphasized in the Annual Report for 1956, these trials were intended to test the ability of the various nitrogenous compounds to release nitrogen over long periods of growth, without in any way implying that such compounds should in practice be utilised solely in the potting mixture without any subsequent top-dressings throughout the whole period of growth. It is, indeed, rather remarkable that sample UFT. 5 used in this way gave a crop yield practically identical with that from hoof and horn supplemented by top-dressings, although the yield data themselves cannot be considered particularly satisfactory. The slow-acting character of the urea-formaldehyde compounds, other than the highly soluble product UFT. 9, is emphasized by the low crop yield from the hoof and horn treatment when applied in the same way as the urea-formaldehyde compounds, that is, entirely in the original potting mixture. Sample UFT. 9 behaved in a manner rather similar to hoof and horn in treatment B, excessive release of nitrogen at the start of the trials and also inadequate release during the later stages of growth resulting in low crop yields. The methylene ether type of urea-formaldehyde compound showed considerable promise, though it is perhaps unwise to judge such compounds by a single example. The related series of methylene ureas UFT. 7-9 showed significantly higher yields from the slower-acting materials UFT. 7 and 8. That UFT. 9 proved the least satisfactory urea-formaldehyde compound could be foreseen from the analytical data in Table I and from the appearance of the plants within the first fortnight of growth; on the other hand it was not anticipated that the relatively insoluble sample UFT. 7 would prove at least as good as the intermediate product UFT. 8.

In addition to the foregoing experiment in clay pots, a second trial with the same fertilizers was also set up at the same time, using glazed containers instead of horticultural clay pots. The containers were fitted with glass draining tubes at the base, any leachings being collected in glass jars suspended below the pots and returned to the soil at intervals. This arrangement eliminated

water-logging of the soil without allowing losses of nitrogen by leaching. The levels of phosphate and potash in the potting mixture were reduced to J.I.P. 2 level in view of the exclusion of leaching losses, but the amounts of nitrogen used were the same as in the clay pots, namely 12 g. nitrogen per plant. The treatments were replicated eight times in all and arranged on the bench in two Youden Squares. Rapid mineralization of nitrogen from hoof and horn in treatment B and from UFT. 8 and 9 (treatments F and G), unrelieved by losses due to leaching, seriously injured the plants in these treatments with the first three weeks. These three treatments had accordingly to be excluded from the trial, and the remaining 32 pots were re-arranged in eight randomised blocks. The more rapid-acting fertilizers thus having been eliminated, the remaining three urea-formaldehyde compounds applied entirely in the original potting mixtures gave yields little different to those from hoof and horn with top dressings. The highest yield, 2,670 g. per plant, was obtained with UFT. 7, the slowest-acting of the methylene ureas, but in view of the further loss of two plants in treatment C, coupled with re-arrangement of the statistical layout soon after the start, it is not proposed to discuss the results in detail; for those treatments in which the plants in glazed pots survived the relatively high concentrations of inorganic nitrogen during the first few weeks, the total crop yields were of the same order of magnitude as in the clay pots. The most interesting feature of the trial probably lies in the loss of all plants in glazed pots receiving treatments B, F and G compared with their survival in ordinary clay pots. Thus drainage from the clay pots, with consequent losses of nitrate, apparently safeguarded these plants from severe injury during rapid decomposition of the nitrogenous fertilizers in the early stages of the trials.

Laboratory studies on rates of mineralization of the nitrogen of urea-formaldehyde samples as used in the glasshouse trials

In order to relate the results of the glasshouse trials to those obtained in the laboratory, mineralization of the nitrogen of urea-formaldehyde samples UFT. 5-9 was also examined in laboratory incubation tests, decomposition of the nitrogenous compounds being studied for periods of up to 16 weeks. The technique of these incubation tests, widely used in these and previous studies, is to mix the nitrogenous compounds under test with moist soil to give a concentration of 300 p.p.m. added nitrogen, and to maintain the treated soils in darkness at constant temperature (23.5°C.). The containers are lightly covered to reduce moisture losses, any such losses being replaced as necessary. The contents of the jars are thoroughly mixed at intervals, and samples removed for determination of ammonia and nitrate. The present series of tests were made in two soils, one an acid soil of pH approximately 5.8, the other an alkaline soil to which 0.5% of calcium carbonate was added to prevent further changes of pH during decomposition of the urea-formaldehyde samples. In order to provide comparison with a conventional organic fertilizer, treatments with horn and hoof were included in the tests. The results are given in Tables IV and V.

TABLE IV
PERCENTAGE MINERALIZATION OF THE NITROGEN OF SOME UREA
FORMALDEHYDE COMPOUNDS WITH HOOF AND HORN FOR COMPARISON,
ON INCUBATION IN AN ALKALINE SOIL WITH 0.5% OF CALCIUM
CARBONATE ADDED

Sample	Mineralization of nitrogen (%)						
	1 week	2 weeks	3 weeks	4 weeks	8 weeks	12 weeks	16 weeks
UFT. 5	13	24	32	36	37	54	55
UFT. 6	16	29	33	40	56	61	65
UFT. 7	2	13	15	19	26	31	34
UFT. 8	30	58	66	69	79	77	68
UFT. 9	35	70	70	68	84	79	84
Hoof and Horn	37	65	70	71	76	72	72

TABLE V

PERCENTAGE MINERALIZATION OF THE NITROGEN OF SOME UREA
FORMALDEHYDE COMPOUNDS WITH HOOF AND HORN FOR COMPARISON,
ON INCUBATION IN AN ACID SOIL (pH 5.8)

Sample	Mineralization of nitrogen (%)						
	1 week	2 weeks	3 weeks	4 weeks	8 weeks	12 weeks	16 weeks
UFT. 5	18	28	32	35	40	48	47
UFT. 6	34	56	64	73	82	86	92
UFT. 7	11	22	27	29	38	46	53
UFT. 8	29	73	78	83	86	86	93
UFT. 9	67	82	83	90	90	81	94
Hoof and Horn	30	64	66	73	75	78	84

The results obtained in the calcareous soil (Table IV) are the more closely related to the glasshouse trials, the compost used in the latter being limed. Under these conditions samples UFT. 5 and 6 both showed fairly slow, steady release of inorganic nitrogen, reaching 54 and 61% mineralization within 12 weeks, with every indication of decomposition continuing. On the basis of these results it could be predicted that these two compounds would be potentially useful as slow-acting nitrogenous fertilizers in soils of similar pH. Such conclusions appear to be substantiated by the results for treatments C and D in the glasshouse trials (Table III), sample UFT. 5 giving the highest yield for any treatment in which all the nitrogen was applied before potting up. As expected, the three related methylene urea compounds showed increasing rates of decomposition with increasing molar ratios of urea to formaldehyde, corresponding to decreasing molecular size. On the basis of these tests sample UFT. 9 would be considered far too rapidly decomposed to be of any merit as a slow-acting fertilizer, and the glasshouse trials support this conclusion, UFT. 9 giving a yield not significantly higher than hoof and horn used entirely in the potting mixture. In contrast, sample UFT. 7 decomposed relatively slowly in the calcareous soil, and indications of inadequate release of nitrogen were noted during the early stages of growth in the glasshouse trials (treatment E). Mineralization of the nitrogen of this sample appeared to continue steadily throughout the incubation tests, however, and the final yields in the glasshouse trials were relatively high. Hoof and horn decomposed relatively rapidly in the laboratory incubation tests, approaching its maximum within three weeks, and gave the lowest crop yields in the glasshouse trials when used without subsequent top-dressings.

As previously noted (2) decomposition of the urea-formaldehyde samples in the incubation tests was, in general, markedly higher in the acid soil (Table V) than in the soil of higher pH; the one exception encountered was sample UFT. 5, which only showed increased mineralization rates in the acid soil during the first two weeks. No explanation of the latter result is available, though it may be mentioned that this was the only sample not used in relatively fresh condition, having been prepared for trials in the previous season. Sample UFT. 6, the methylene ether compound, again showed progressively increasing decomposition throughout the tests, and the related methylene ureas UFT. 7-9 showed increasing rates of decomposition with increasing ratios of urea to formaldehyde in the products. Decomposition of hoof and horn was not markedly affected by soil pH.

On the basis of results obtained during 1956 and 1957 it appears that both analytical data for urea-formaldehyde compounds and laboratory incubation studies on their rates of decomposition in soil can provide some guide to their value as slow-acting fertilisers in plant growth trials. Under the conditions of the present tests, however, using relatively heavy applications prior to planting, it should be recognised that low yields can arise from either of two different reasons.

Thus compounds decomposing too slowly in the soil to meet the needs of the plant at the selected level of application cannot result in maximum yields, whilst compounds decomposing relatively quickly will lead to excessive levels of ammonia and nitrate in the soil at the early stages of growth, accompanied by stunting and root-damage if used at similar concentrations. With regard to nitrogen nutrition, optimal yields in such trials thus depend on the balance of these two effects, and the results are accordingly unlikely to be independent of the concentration of nitrogen selected for the trials; lower levels of added nitrogen would almost certainly favour somewhat more rapid-acting fertilizers, not only by avoiding any toxic effects from high levels of nitrate in the early stages but also because high rates of mineralization tend to be coupled with high values for limiting "availability" in the soil. It may also be noted that, despite the clear general relation between analytical data (Table I) and the laboratory incubation tests (Tables IV and V) or glasshouse trials (Tables II and III) within a range of closely related samples, such as the methylene ureas UFT. 7, 8 and 9, when applied to less closely related samples the analytical data alone may not be entirely adequate as a guide to rates of decomposition in soil. This difficulty arises in part from the somewhat complex chemistry of the compounds, but rather more from the fact that the reaction products are in fact mixtures containing varying proportions of different urea-formaldehyde compounds together with any unreacted urea. Thus a given proportion of soluble nitrogen or urea-formaldehyde ratio can be obtained from numerous combinations of different components.

Despite any such difficulties in the characterization of mixed urea-formaldehyde products, and any limitations of the present glasshouse trials, it is readily apparent that suitably formulated urea-formaldehyde compounds possess the valuable property of releasing inorganic nitrogen slowly and fairly steadily, and in this respect are greatly superior to natural organic compounds such as hoof and horn, normally regarded as the best slow-acting nitrogenous material for potting mixtures and similar uses. Whilst the development of urea-formaldehyde compounds still requires considerable study before it is certain that the best formulations have been achieved, such compounds appear to offer much promise, particularly for specialized usage as in potting composts.

A NOTE ON METHYLENE ETHER COMPOUNDS AS POSSIBLE SLOW-ACTING NITROGENOUS FERTILIZERS

Existing studies of urea-formaldehyde compounds as nitrogenous fertilizers are largely devoted to materials prepared by reaction under acid conditions and with urea-formaldehyde ratios >1 , the products generally being considered to consist of methylene ureas of various chain-lengths. As previously noted (3), however, products prepared with urea-formaldehyde ratios <1 can show favourable characteristics in laboratory incubation tests, and sample UFT. 6, a methylene ether prepared at a U/F ratio of 0.67, showed considerable promise in the glasshouse trials with tomato plants during 1957. In general, our limited experience with such compounds in the past has suggested that relatively slow, steady mineralization of nitrogen can readily be achieved, at least in soils which are not too acid, the form of the curves for mineralization of nitrogen in laboratory incubation tests being preferable to those for methylene urea compounds as generally prepared under acid conditions with U/F ratios >1 .

The methylene ethers appear to have attracted little or no attention as possible slow-acting nitrogenous fertilizers; a full investigation of their properties would involve considerable further research which, owing to the demands of other work, is unlikely to be undertaken here at present. A very brief examination of certain properties of some methylene ether products has, however, been made and, as the work is unlikely to be followed up in the near future, is now outlined in this short note.

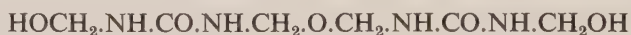
In its simplest form the formation of a methylene ether may be represented by the condensation of two molecules of monomethylol urea with the elimination of water:—



Reactions of this type proceed readily under alkaline conditions. Brief reference to certain published work on such compounds was made in the Annual Report for 1956, and, in particular, the work of Zigeuner (7) may be cited.

Preliminary studies were planned to test the effect of urea-formaldehyde ratio and period of reaction upon the rates of decomposition of the products in soil. The general procedure for preparing the samples was to dissolve the urea in sufficient formalin to give the desired U/F ratio, the solution being made alkaline by the addition of solid potassium hydroxide (2.5 g. per 100 g. urea). The temperature was maintained below 25°C. by a cooling coil during the early stages of reaction, after which the reaction mixture stood at room temperature. The products were filtered off, washed with alcohol and air-dried; sample 146(a), only, was recrystallised from hot water. Details of the preparations are given in Table VI. Precipitation of urea-formaldehyde compounds was most rapid at a U/F ratio of 1 : 1, but the maximum yields were obtained at ratios of 0.67 and 0.5. In the 147-series of samples the yield increased with the period of standing, being far from complete after two days. As might be expected, the nitrogen content of the samples increased, and the formaldehyde equivalent decreased, as the ratio of urea to formaldehyde was increased in the reaction mixture. Values for the U/F ratio of the products, calculated from the analytical data in Table VI, tend to increase with increasing U/F ratio of the reactants, but, as previously observed with methylene urea compounds, over a far more restricted range. The product obtained at a U/F ratio of 0.5 in the reactants itself showed a very similar U/F ratio of 0.51, coinciding with maximum yield in the 146-series. The numerical values for the U/F ratio of the products show that the simple methylene ether compound (U/F=1) already used to illustrate the type of reaction involved could only be present at very low concentrations in these products, if at all. The values are, however, in accordance with the obvious possibilities of further methylol ($-\text{CH}_2\text{OH}$) groupings being attached to the molecule. Thus addition of one methylol grouping would give a U/F ratio of 0.67, two methylol groups would correspond to a U/F ratio of 0.5, and three such groupings to 0.4.

The chemistry of these compounds has been investigated by Zigeuner *et al.* (8), who used a scheme for their identification based on reaction with 2, 4-dimethyl phenol. Following Zigeuner's methods it was concluded that the main component of samples 146(a)–(e) was of the type:—



This compound would have a molar U/F ratio of 0.5, a value which lies well within the range calculated in Table VI. Small amounts of other methylol derivatives were also isolated, which may well account for the observed variations in the calculated U/F values. The formula given above, containing two terminal methylol groups, corresponds to a theoretical composition of 25.2% nitrogen and a formaldehyde equivalent of 54.1%. Analytical data for sample 146(c), prepared at a U/F ratio of 0.5, are in good agreement with these calculated values, and lend support to conclusions based on Zigeuner's methods, using 2, 4-dimethyl phenol. Samples prepared with a greater excess of formaldehyde (lower U/F ratio) may well be expected to contain a higher proportion of methylol groups, and conversely, samples of relatively high U/F ratio would have a lower formaldehyde equivalent. It may also be noted that, as in the methylene urea series discussed elsewhere (6), the possibility of further condensation to form chain structures also exists. With the methylene ethers such condensation processes would not effect the U/F ratio of the product, but would raise the nitrogen content and formaldehyde equivalent somewhat owing to elimination of water.

Soil incubation tests, using both an acid and a limed soil, are shown for samples 146(a)–(e) in Table VII and for 147(a)–(c) in Table VIII.

TABLE VI

THE PREPARATION OF SOME UREA-FORMALDEHYDE COMPOUNDS, TOGETHER WITH ANALYTICAL DATA FOR THE PRODUCTS

Samples	U/F ratio	Period of reaction	Notes	Yield*	Total nitrogen %	Total formaldehyde %	U/F ratio of product
146 (a)	0.25	3 weeks	Precipitated very slowly. Recrystallized	15	25.0	—	—
146 (b)	0.25	"	" " "	30	24.3	58.5	0.45
146 (c)	0.5	"	Precipitated overnight	100	25.8	54.0	0.51
146 (d)	0.67	"	" "	82	27.6	48.6	0.61
146 (e)	1.00	"	Precipitated rapidly	30	27.7	49.0	0.61
147 (a)	0.67	24 hours		45	26.0	—	—
147 (b)	0.67	48 hours		76	27.0	—	—
147 (c)	0.67	3 weeks		110	26.6	—	—

* Yield in grams per 100 g. urea

TABLE VII
EFFECT OF MOLAR RATIO OF UREA TO FORMALDEHYDE (U/F RATIO) IN THE REACTION MIXTURE ON RATES OF
MINERALIZATION OF NITROGEN IN TWO SOILS

Soil	Sample	U/F ratio of reactants	Mineralization of nitrogen (%)							
			1 week	2 weeks	3 weeks	4 weeks	8 weeks	12 weeks	16 weeks	26 weeks
Limed (pH 8.0)	146 (a)*	0.25	12	27	42	53	70	70	77	76
	146 (b)	0.25	4	11	17	25	44	52	61	68
	146 (c)	0.5	19	32	39	42	49	50	56	61
	146 (d)	0.67	18	33	44	51	62	61	69	73
	146 (e)	1.00	19	37	52	61	74	76	79	84
Acid (pH 5.8)	146 (a)*	0.25	43	67	76	82	88	93	94	100
	146 (b)	0.25	38	67	80	84	93	97	96	101
	146 (c)	0.5	34	48	56	62	72	81	82	97
	146 (d)	0.67	42	62	72	80	81	92	91	102
	146 (e)	1.00	49	70	80	84	92	96	93	99

* Recrystallized product.

Referring firstly to the effect of U/F ratio in the reaction mixture (Table VII), in the limed soil samples 146-(b) to (e) show a well marked increase in rate of decomposition with increasing ratios of urea to formaldehyde from U/F 0.25 to 1.0 during the first 8 weeks of the incubation tests. For samples 146(c) to (e) the relationship was in fact maintained throughout the whole period of the tests (26 weeks), but sample 146(b), prepared at the lowest U/F ratio, decomposed more rapidly than 146(c) in the later stages of incubation. Sample 146(a), differing from the remaining samples in being recrystallised from hot water, showed a higher rate of mineralization than the corresponding sample 146(b) (not recrystallised). In the acid soil all samples decomposed more rapidly, products 146(c) to (e) again showing increasing rates of mineralization throughout with increasing U/F ratio from 0.5 to 1.0. Sample 146(b), however, prepared at the lowest U/F ratio (0.25), was an exception to this general trend, showing a high rate of decomposition throughout. Thus in both the acid and the limed soils, rates of mineralization increased with U/F ratios from 0.5 to 1.0 in the reactants, but material prepared at a lower initial U/F ratio of 0.25 tended to depart from this general relation in the acid soil, and also during the later stages of decomposition in the limed soil.

TABLE VIII
EFFECT OF PERIOD OF REACTION UPON THE RATE OF MINERALIZATION
OF THE NITROGEN OF THE PRODUCTS IN TWO SOILS, THE U/F RATIO OF
THE REACTION MIXTURE BEING 0.67 THROUGHOUT

Soil	Sample	Period of reaction	Mineralization of nitrogen (%)						
			1 week	2 weeks	3 weeks	4 weeks	8 weeks	16 weeks	26 weeks
Limed	147 (a)	24 hours	19	31	42	53	82	76	81
	147 (b)	48 hours	20	28	40	46	65	70	79
	147 (c)	3 weeks	18	29	38	47	66	71	81
Acid	147 (a)	24 hours	47	72	83	90	98	97	98
	147 (b)	48 hours	42	66	72	81	90	94	99
	147 (c)	3 weeks	46	69	80	84	94	97	100

The results in Table VIII suggest that, despite marked differences in yield with period of reaction (Table VI), the rates of decomposition of the products do not differ very markedly. Such differences as were found, however, indicate greater ease of decomposition of the first-formed products of reaction, this effect being most marked in the limed soil on incubation for periods of 4 and 8 weeks. Decomposition was, as usual, more rapid in the acid than in the limed soil.

On the basis of soil incubation tests in the laboratory the general pattern of release of inorganic nitrogen from the methylene ether compounds shows very considerable promise, giving a better indication of continuing mineralization of nitrogen over long periods of time than was the case for the methylene ureas; like the latter compounds they appear to be sensitive to soil pH and hence too rapidly decomposed in acid soils. In practice, however, there is no reason why the degree of acidity which would make the rates of decomposition of urea-formaldehyde compounds undesirably high should be allowed to develop. In conclusion, it must be stressed that practical tests with methylene ethers as sources of nitrogen for plant growth have been extremely limited as yet, and in view of their relatively high formaldehyde equivalent it remains to be established that they are entirely harmless to plant growth under all reasonable conditions.

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6. THE EFFECT OF NUTRIENT CONCENTRATION IN LIQUID FEEDS UPON CROP YIELDS AND FRUIT QUALITY OF TOMATOES

by

G. W. WINSOR, J. H. L. MESSING & J. N. DAVIES

As part of a series of trials on the use of liquid feeding in tomato nutrition, the present experiment was designed primarily to test the effects of concentration of nutrient on cropping and fruit quality, accompanied by studies of nutrient concentration both in the plants and in the soil.

Layout and experimental procedure

The nutrient solutions used in this trial, which was laid down in house C3, contained potassium nitrate and ammonium sulphate, the ratio of potash (K_2O) to nitrogen being 1.75 throughout. Four concentrations of solution were used, as follows:—

Treatment	Concentration in diluted feed	
	Nitrogen	Potash (K_2O)
A	<i>p.p.m.</i> 75	<i>p.p.m.</i> 131
B	150	263
C	225	394
D	300	525

Apart from the inclusion of a small quantity of phosphate at the start of the season, the composition of the solutions remained unchanged throughout and, except for small amounts used in overhead damping, all water applied to the plots contained nutrients as stated above. In addition to the nutrients applied in solution, the same mixture of potassium nitrate and ammonium sulphate was applied in solid form before planting, plots receiving treatments A—D being treated at rates of 2, 4, 6 and 8 oz. per square yard respectively in order to introduce differential treatments at an early stage of growth. Superphosphate was applied uniformly throughout at the rate of 6 oz. per square yard.

The four treatments were replicated in four randomized blocks, giving a total of 16 recorded plots with additional guard plots at the north and south ends of the house. The plots were separated by strips of asbestos sheeting inserted vertically into the soil to a depth of 6 inches and protruding approximately 2 inches above soil level in order to avoid surface wash.

Individual plots contained 24 plants, of which 16 were recorded and the remainder served as guard rows adjoining the asbestos sheeting between the plots. The variety used in the first year of the trials was "L.M.R.1."

The nutrient solutions were applied by hose, using automatic diluting equipment consisting of a water-operated pump injecting the concentrated feeds into a mixing chamber. The application of the diluted feeds was controlled by meter, and was equal for all plots. Some difficulty was experienced in keeping the plants from wilting during hot weather, despite liberal application of water.

Representative soil samples were taken for analysis from all plots before planting, and four times subsequently during the growing season. Samples of foliage were collected from all plots during May and June, and stored for analysis after drying at 80°C. Fruit was, in general, picked twice a week, being weighed and graded for each plot as already described in connection with trials on magnesium deficiency in houses D1 and D2.

Results

Soil samples from all 16 plots at the five dates of sampling were analysed separately for "available" potash and phosphate, and determinations of *pH* and *pC* were also made. Mean values for percentage potash soluble in 0.5 N-acetic acid, based on the four replications of each treatment, are given in Table I.

TABLE I
LEVELS OF "AVAILABLE" POTASH (K_2O) IN SOIL SAMPLES FROM EACH
TREATMENT AT FIVE DATES OF SAMPLING

Treatment		A	B	C	D
Concentration in diluted feed (p.p.m.)	N	75	150	225	300
	K_2O	131	263	394	525
<i>Date of sampling</i>		%	%	%	%
26/2/57		0.034	0.031	0.030	0.029
23/4/57		0.043	0.049	0.052	0.067
20/5/57		0.040	0.041	0.045	0.050
17/6/57		0.030	0.035	0.044	0.057
18/9/57		0.028	0.037	0.051	0.069
Mean*		0.035	0.041	0.048	0.061

NOTE:—Each value is the mean based on analyses of samples from four plots.

* Mean of values from April to September, excluding the preliminary sampling (26/2/57) before treatments commenced.

The initial analysis prior to planting shows reasonable uniformity in potash content throughout, whilst samples taken subsequently show, in general, increasing levels of soil potash with increasing concentrations of soluble fertilizer. None of the values could be regarded as excessively high, however, and comparison of the initial and final analyses (February and September) shows that only the two highest concentrations of nutrients (treatments C and D) caused any appreciable accumulation of potash in the soil.

Results for soil *pH* (Table II) show that the soil initially had a *pH* value of about 7.2, this decreasing during cropping with increasing concentrations of nutrients applied, the lowest individual value recorded being 5.7 in one plot receiving treatment D, in September. Thus the results show the development of acidity related to the concentration of nutrients applied and generally increasing in extent as the season progressed, though in no case would the resulting *pH* values be considered to be directly harmful to plant growth.

TABLE II

pH VALUES IN SOIL SAMPLES FROM EACH TREATMENT AT FIVE DATES
OF SAMPLING

Treatment		A	B	C	D
Concentration in diluted feed (p.p.m.)	N	75	150	225	300
	K ₂ O	131	263	394	525
<i>Date of sampling</i>					
26/2/57		7.2	7.2	7.3	7.2
23/4/57		6.7	6.7	6.7	6.6
20/5/57		6.9	6.8	6.5	6.4
17/6/57		7.0	6.8	6.5	6.3
18/9/57		7.0	6.6	6.2	5.9
Mean*		6.9	6.7	6.5	6.3

NOTE:—Each value is the mean based on determinations for four individual plots.

* Mean of values from April to September, excluding the preliminary sampling (26/2/57) before treatments commenced.

Results for soluble salts in the soil, measured at the conventional water/soil ratio of 2.5 : 1 and expressed as *pC* values, are given in Table III.

TABLE III

pC VALUES OF SOIL SAMPLES FROM EACH TREATMENT AT FIVE DATES
OF SAMPLING

Treatment		A	B	C	D
Concentration in diluted feed (p.p.m.)	N	75	150	225	300
	K ₂ O	131	263	394	525
<i>Date of sampling</i>					
26/2/57		3.21	3.26	3.22	3.23
23/4/57		2.91	2.85	2.81	2.72
20/5/57		3.02	2.88	2.81	2.78
17/6/57		2.98	2.85	2.77	2.75
18/9/57		3.07	2.97	2.85	2.73
Mean*		3.00	2.89	2.81	2.75

NOTE:—Each value is the mean based on determinations for four individual plots.

* Mean of values from April to September, excluding the preliminary sampling (26/2/57) before treatments commenced.

The results show *pC* values decreasing as the season progressed, the lowest values corresponding to the highest concentration of nutrients in the liquid feeds. At the highest level of nutrient applied the *pC* values indicated a rather high concentration of soluble salts in the soil, without approaching the particularly undesirable values not infrequently encountered in old glasshouse

soils. In view of uncertainties associated with the conventional procedure for pC measurements in soils (1) it is not proposed to discuss these results any further at present, though particular attention is being given to this subject meanwhile.

Samples of foliage for analysis were taken from all 16 plots during May, and again during June, the fifth leaf below the tops being selected for this purpose. No significant differences were found in the percentage dry-matter content of foliage from plants receiving the four different concentrations of nutrient. Determinations of total nitrogen, phosphorus and potassium were made on all samples. The results are summarized in Table IV, each value being the mean of samples from four plots receiving identical treatments.

TABLE IV
THE NITROGEN, PHOSPHATE (P_2O_5) AND POTASH (K_2O) CONTENTS OF
LEAF SAMPLES FROM PLANTS RECEIVING FOUR CONCENTRATIONS OF
SOLUBLE FERTILIZER AT TWO DATES OF SAMPLING.

Treatment		A	B	C	D
Concentration in diluted feeds (p.p.m.)	N	75	150	225	300
	K_2O	131	263	394	525
	<i>Date of sampling</i>	%	%	%	%
Nitrogen	9/5/57	5.34	5.45	5.65	5.55
	18/6/57	4.87	5.32	5.53	5.49
Phosphate (P_2O_5)	9/5/57	1.29	1.31	1.26	1.25
	18/6/57	0.80	0.82	0.82	0.83
Potash (K_2O)	9/5/57	5.96	6.14	6.01	6.16
	18/6/57	6.81	6.61	6.92	7.17

NOTE:—Each value is the mean based on analyses of foliage from four plots.

The results for nitrogen in Table IV show a tendency for increasing nitrogen content of the foliage with increasing concentration of the nutrient solutions; statistical analysis shows that, at the second date of sampling (18/6/57), the nitrogen content of foliage from treatment A was significantly lower than that from the remaining treatments. None of the values for nitrogen content of the foliage would be regarded as in any way low, however, and it is apparent that at no stage was there any likelihood of nitrogen deficiency, even at the lowest concentration of nutrients applied. The phosphorus content of the leaves showed no appreciable variation between treatments, and again would be regarded as fully adequate; the values obtained at the first date of sampling are, indeed, relatively high. Values for potassium content of the foliage were quite high throughout, and showed only a slight tendency to increase with increasing concentrations of this element in the nutrient solutions; differences between treatments were not statistically significant at either date of sampling. To summarize the results of the tissue analyses, the levels of nitrogen, phosphorus and potassium in leaf samples from all treatments showed fully adequate levels of all three elements, and only in the case of nitrogen at the second date of sampling were the analytical differences statistically significant. Thus any effects of the treatments upon fruit production and quality appear unlikely to be due to deficiencies of any of these three macro-nutrients during growth, a conclusion fully supported by the lack of visual differences in growth and leaf colour after the early stages of the trial.

TABLE V

TOTAL FRUIT (LB. PER PLANT) FROM INDIVIDUAL PLOTS IN RELATION TO
NUTRIENT CONCENTRATION IN THE LIQUID FEEDS

Treatment		A		B		C		D	
Concentration in diluted feed (p.p.m.)	N	75		150		225		300	
	K ₂ O	131		263		394		525	
		Plot	Yield	Plot	Yield	Plot	Yield	Plot	Yield
		3	9.03	2	8.97	1	7.88	4	8.86
		7	9.21	8	6.95	5	7.77	6	7.71
		11	8.02	12	7.52	10	6.43	9	6.15
		14	7.20	15	6.06	13	6.37	16	6.23
Mean			8.37		7.38		7.11		7.24

NOTE:—Plots 1 & 16 are at the north-east and north-west respectively,
plots 8 and 9 at the south-east and south-west.

The total yields of fruit from the 16 plots are given in Table V; the yields from this variety ("L.M.R.1") were considerably below those obtained from "Potentate" with trickle irrigation in the adjoining house C4. At the spacings used, plants of variety "L.M.R.1." made a very dense stand with heavy foliage, and, whereas those plants bordering the path carried a relatively heavy crop, the inner plants showed a poor set and small fruit-size in the middle trusses. Heavier leafing and wider spacing would almost certainly have improved the yields. Statistical analysis of the total yields of fruit per plot, including separation of the treatment differences into a linear component and a remainder component, shows that a significant reduction in crop resulted from the use of the more concentrated nutrient solutions, the crop from plots receiving the weakest solution (treatment A) being rather heavier than from the remaining three treatments. The distribution of crop yields within the house showed marked positional differences of an unexpected nature, the heaviest crop occurring in the north-east quarter of the house and the lightest yields in the north-west quarter. The latter result is not easy to explain, as plants at the south end of the houses generally show the best growth, particularly in the early stages. Differences between blocks with respect to total cropping were significant statistically at $P=0.01$.

The grading of the fruit into grades A–D, as already defined in the current report on magnesium deficiency, is given in Table VI, each value being the mean of four plots; grades A and B represent uniformly coloured fruit of regular and somewhat irregular shape respectively, whilst grade C is irregularly coloured.

Statistical analysis, including calculation of the linear regression component, shows that the yield of grade A fruit increased significantly ($P=0.05$) with nutrient concentration, whereas the yield of grade C fruit decreased significantly ($P=0.01$) with concentration. Since the increase in grade A fruit with concentration was accompanied by some reduction in total crop, the proportion of grade A fruit increased still more markedly. Mean values for graded fruit, expressed as percentages of the total crop, are given in Table VII. From these data it appears that the higher proportion of grade A fruit at high nutrient concentrations represents an improvement in uniformity of pigmentation accompanied by some improvement in regularity of shape. It may also be noted that variety "L.M.R.1." gave a far lower proportion of somewhat irregular shape (grade B) and of highly irregularly shaped fruit (grade D) than did "Potentate" in adjoining houses.

TABLE VI

GRADING OF FRUIT (LB. PER PLANT) FROM TOMATO PLANTS
GROWN AT FOUR DIFFERENT CONCENTRATIONS OF NUTRIENT SOLUTION

Treatment	Concentration (p.p.m.)		Grading				Total*
	N	K ₂ O	A	B	C	D	
A	75	131	2.58	1.05	3.85	0.39	7.87
B	150	263	2.74	0.66	3.00	0.51	6.91
C	225	394	3.04	0.61	2.54	0.58	6.77
D	300	525	3.27	0.48	2.54	0.53	6.82

NOTE:—Each value is the mean of four plots.

* Excluding fruit picked green at the end of the season.

TABLE VII

GRADING OF FRUIT, EXPRESSED AS PERCENTAGES OF THE TOTAL
GRADED CROP, FROM TOMATO PLANTS GROWN AT FOUR CONCENTRA-
TIONS OF NUTRIENT SOLUTION

Treatment	Concentration (p.p.m.)		Grading			
	N	K ₂ O	A	B	C	D
A	75	131	32.4	13.6	48.9	5.1
B	150	263	39.6	9.6	43.5	7.3
C	225	394	44.5	9.2	37.7	8.6
D	300	525	48.1	7.2	36.9	7.8

Conclusions

The results of the first year of this trial show that both quality and quantity of fruit were affected by the amounts of nutrient applied in the liquid feeds. Thus total crop yields decreased, and the proportion of grade A fruit increased, with increasing nutrient concentration. Analyses of the foliage, coupled with observations on the appearance of the plants, show that even at the lowest concentration of nitrogen and potash applied no shortage of these nutrients resulted. The observed effects on cropping and quality thus appear to be of a physical rather than of a nutritional nature, related to the concentrations of soluble salts present in the soil.

Repetition of the trial will be necessary before the conclusions can be regarded as fully established.

REFERENCE

1. WINSOR, G. W. & DAVIES, J. N. (1958). A critical re-examination of the conventional conductivity (pC) test for soluble salts in soils. *Rep. Glasshouse Crops Res. Inst.* 1956, 84-92.

7. STUDIES ON POTASH/NITROGEN RATIO IN NUTRIENT SOLUTIONS, USING TRICKLE IRRIGATION EQUIPMENT

by

G. W. WINSOR, J. N. DAVIES & J. H. L. MESSING

Experiments on the liquid feeding of tomatoes were started in 1957, the objects being firstly, to explore the use of trickle irrigation equipment in replicated nutritional trials with small plots, and secondly, to study the effects of varying the potash/nitrogen ratio on the growth and cropping of tomatoes.

The use of irrigation equipment to supply both water and nutrients has certain obvious advantages for controlled experiments in plant nutrition, but although such equipment is now used commercially on a considerable scale, its application to replicated experiments presents some difficulty. In particular, the simplicity of single irrigation lines running the length of the glasshouse has to be replaced by a complex system of mains and short irrigation lines throughout the area. In addition, the inclusion of several different treatments within a limited cropping space reduces the flow-rate through each diluter, and thus involves special modification of the latter for satisfactory operation.

Treatments and layout

Four treatments were included in the first series of trials on plant nutrition using low-level irrigation equipment, these being as follows:—

- | | | |
|----|--------------------------------------|-------|
| A. | Potash/nitrogen ratio (K_2O/N) = | 1.0:1 |
| B. | „ „ „ „ | 1.5:1 |
| C. | „ „ „ „ | 2.0:1 |
| D. | „ „ „ „ | 2.5:1 |

It is commonly held that the ratio of potash to nitrogen should not be too low in the early stages of growth, but that the proportion of nitrogen can, with advantage, be increased later in the season. Figures for total uptake of nutrients by the tomato crop show a potash/nitrogen ratio of about 2:1, and rather similar ratios are found in many base fertilizers and in certain liquid feeds. The potash/nitrogen ratios used in the present trials were chosen to cover the range likely to be of practical interest.

In commercial practice it is customary to vary the timing and composition of fertilizer applications in relation to plant growth. For experiments with widely differing treatments this procedure would introduce questions of judgment which are not amenable to objective experimentation unless covered by numerous sub-divisions of the treatments in factorial combination. In recent years, however, very satisfactory crops have been grown at a constant concentration of all nutrients in the liquid feed, the amounts of nutrient applied being directly related to the water requirements of the crop (1). In the present experiments the potash/nitrogen ratio of each liquid feed remained constant throughout the season, all water applied other than as overhead damping containing nutrients. As the total water requirements of the crop were not known with certainty, however, and as the amounts of nutrient applied would be small during the important early stages of growth, the nutrient solutions were supplied at relatively high concentrations at first, and subsequently weakened as the season progressed and the total amounts of solution increased. At any one date of application the nitrogen content of the solutions was the same for all four treatments.

The experiment was sited in the western span of a block of aeroplane-type houses running north-south, the cultivated area being 105×14 feet. The plants were set out in two double lines along the centre of the house, with additional single lines at the east and west, each plant being beside a heating pipe and spaced at 15 inch intervals along the lines. The double rows of plants were divided into four blocks (north-east, south-east, south-west, north-west), each block being sub-divided into four plots within which the four treatments were randomised. The two single lines of plants at the east and west sides were each regarded as separate blocks in which each treatment occurred once. All plots contained 18 plants. The number of recorded plants in each plot was 14, with guard plants adjoining the asbestos sheeting which separates the plots. In the central four blocks the plots thus consisted of sections of a double row of plants, with four guard plants, one at each corner. In the outside blocks the plots were in single line, with two guard plants, one at each end; of the remaining sixteen plants, two were selected at random in each plot for studies of total nutrient uptake, again leaving fourteen plants to be recorded in the main experiment. Additional guard plots were planted at the north and south ends of the house, numbering eight in all.

Stable manure was dug in over the whole house at the rate of 40 tons per acre, and composted straw at 35 tons per acre. Triple super-phosphate was applied uniformly throughout at the rate of 2 ounces per square yard, with an additional dressing of 1 ounce of superphosphate (18% P_2O_5) and 2 ounces of ground limestone per yard along the planting positions. No other base fertilizer was used. The house was planted on March 12th.

The dilution equipment and controls were located over the heating duct at the south end of the house, each diluter being connected to a separate water-meter to ensure equal watering throughout. Samples of the diluted nutrient solutions were collected at intervals for analysis as a check on the performance of the diluters. Nutrient solutions were applied daily throughout most of the season, a total of 31.6 gallons per plant being given up to October 7th. The fertilizers used consisted of potassium nitrate, potassium sulphate and urea, thus supplying nitrogen and potash but no phosphate. The concentrations of nitrogen in the diluted feeds were:—

13th March	—	6th April	267 p.p.m.
8th April	—	9th May	235 „
10th May	—	19th June	200 „
20th June	—	8th August	160 „
9th August	—	7th October	133 „

The plants grew strongly and showed little variability within plots. No obvious differences in general appearance were noted among the various treatments, but marked effects of position in the house became apparent. Thus those plants adjoining the glass along the west of the house were shorter, with thinner stems and a less vegetative appearance, in contrast to the very lush growth on the more shaded east side.

The total weights of fruit from each of the 24 plots were recorded throughout the season, normally twice each week. Fruit from each plot was also graded into four categories (A-D) as defined in the article on magnesium deficiency (this Report, p.99). After combining fruit from plots receiving identical treatments, the fruit was sized on a grading machine (grade A) and by hand (grade B), and the irregularly coloured fruit (grade C) further sub-divided as described in the article on fruit composition (this Report, p.40).

Results

Crop yields from all plots are given in Table I, together with the grading of the fruit into categories A-D. The weight of crop picked was relatively high, but included much fruit of uneven

colour. The yields showed a marked effect of position across the house, the heaviest crop being on the exposed side and the lightest crop on the more shaded areas towards the east (inner) side.

The weights of grade A fruit were relatively small throughout, but mean values for the treatments (Table I) increased with potash/nitrogen ratio. Analysis of variance on the basis of treatments and blocks, with sub-division of the treatment effects into a linear component and a remainder component, showed the response to potash/nitrogen ratio to be statistically significant; the mean increase in grade A fruit was 0.22 ± 0.06 lb. per plant per treatment increment. Despite this significant response to the experimental treatments it is unfortunate that the proportion of grade A fruit was not higher. The mean weights of grade B fruit also increased somewhat with potash/nitrogen ratio. Analysis of the combined data for grades A and B again shows a significant rise with potash/nitrogen ratio, the yield increase being 0.35 lb. per plant per treatment increment. The weights of irregularly coloured fruit (grade C) decreased with potash/nitrogen ratio from 1.5:1 to 2.5:1, the effect being significant at $P=0.05$.

TABLE I
CROP YIELDS AND GRADING OF FRUIT (LB. PER PLANT) IN RELATION TO
THE POTASH/NITROGEN RATIO (K_2O/N) OF THE NUTRIENT SOLUTIONS

Potash/nitrogen ratio	Plot number	Block	Grading				Graded total	Green fruit	Total
			A	B	C	D			
$K_2O/N = 1:1$	3	I	0.93	1.74	6.42	1.92	11.01	1.37	12.38
	5	II	0.93	1.43	6.56	1.45	10.37	0.88	11.25
	10	III	0.79	1.45	7.02	1.65	10.91	0.98	11.89
	13	IV	1.77	1.83	6.04	2.06	11.70	0.79	12.49
	19	V	1.11	1.90	6.96	1.74	11.71	0.49	12.20
	21	VI	1.14	1.91	9.56	2.25	14.86	0.70	15.56
	Mean	I-VI	1.11	1.71	7.09	1.85	11.76	0.87	12.63
$K_2O/N = 1.5:1$	2	I	0.84	1.99	6.79	2.00	11.62	1.05	12.67
	6	II	1.11	1.52	6.35	1.43	10.41	0.98	11.39
	11	III	1.67	2.04	4.85	1.77	10.33	0.66	10.99
	16	IV	1.54	1.99	7.44	1.81	12.79	0.90	13.68
	17	V	1.39	1.75	7.37	2.05	12.56	0.59	13.15
	23	VI	1.96	2.00	10.41	1.88	16.25	1.18	17.43
	Mean	I-VI	1.42	1.88	7.20	1.82	12.33	0.89	13.21
$K_2O/N = 2:1$	1	I	1.29	2.32	6.01	2.00	11.63	0.78	12.40
	8	II	1.33	1.57	4.95	1.43	9.28	0.74	10.02
	12	III	1.66	2.06	5.52	1.62	10.86	0.67	11.53
	14	IV	1.24	1.50	7.28	1.96	11.98	0.87	12.85
	18	V	2.00	1.87	6.53	1.91	12.31	0.54	12.85
	22	VI	1.96	2.00	9.21	2.15	15.32	0.86	16.18
	Mean	I-VI	1.58	1.89	6.58	1.85	11.90	0.74	12.64
$K_2O/N = 2.5:1$	4	I	1.58	2.10	4.85	1.89	10.42	1.25	11.67
	7	II	1.21	2.00	5.86	1.87	10.94	0.96	11.90
	9	III	1.70	1.83	5.38	1.92	10.83	1.04	11.87
	15	IV	1.43	1.65	7.12	1.54	11.74	0.67	12.41
	20	V	2.11	2.31	5.76	1.43	11.61	0.63	12.24
	24	VI	2.79	2.83	8.00	2.18	15.80	0.84	16.64
	Mean	I-VI	1.80	2.12	6.16	1.81	11.89	0.90	12.79

Mean values for the percentages of the total graded crop represented by grades A-D are given in Table II. The proportion of grade A and B fruit increased with potash/nitrogen ratio whereas the percentage of grade C fruit decreased. The proportion of irregularly coloured fruit (grade C) was undoubtedly high, but it may be noted that the scheme of grading was very strict. Thus fruit of grades A and B was definitely uniform in colour, the standard being particularly high. Similarly grade A fruit was as regular in shape as tomatoes can be, grade B fruit was somewhat less regular in shape but never grossly misshaped, and grade D contained much fruit commonly classed as "Blues". Grade C included a proportion of fruit which would ripen normally within 1-2 days, and should not all be regarded as "blotchy" or "waxy".

TABLE II
MEAN VALUES FOR THE GRADING OF THE CROP IN RELATION TO
POTASH/NITROGEN RATIO, EXPRESSED AS PERCENTAGES OF THE TOTAL
FRUIT GRADED

Potash/nitrogen ratio	% Grade A	% Grade B	% Grade C	% Grade D
1:1	9.5	14.5	60.3	15.7
1.5:1	11.5	15.3	58.4	14.8
2:1	13.3	15.9	55.4	15.5
2.5:1	15.2	17.8	51.8	15.2

In addition to the simplified grading scheme for all plots, the combined pickings from each treatment were further graded according to size and pigmentation. Potash/nitrogen ratio had no obvious effect on fruit size in the first year of the experiment. Early in July it was noted that the quality of fruit picked varied with position in the house, much of the very worst fruit being on the shaded (east) side. The irregularly coloured fruit (grade C) from plots 1-4 along the shaded east side and from plots 21-24 along the exposed west side was therefore graded separately into a further six categories from July 23rd onwards. The most interesting feature of the results is shown in Table III. In late July and early August a very high proportion of the irregularly coloured fruit from plots 1-4, situated on the shaded east side of the house, was classified as C6, this being severely affected fruit showing "waxy" areas generally accompanied by marked vascular browning and surface pitting. In contrast, irregularly coloured fruit from the exposed plots 21-24 was mainly classified as showing mild or severe green or yellow-green areas in the walls. The abnormally high proportion of "waxy" fruit on the strong leafy plants in plots 1-4 decreased markedly in early August, and such fruit was almost entirely absent after the middle of the month. Despite the severity of the ripening disorders at the shaded side of the house, the proportion of the total crop showing irregular colour in any form (grade C) was somewhat higher on the exposed side of the house; statistical analysis of the data for 23 dates of picking shows the effect of position to be significant at $P=0.05$.

Samples of foliage were collected for analysis from all 24 plots on two occasions during the season, the fifth leaf from the top of the plant being selected in each case. Mean values for the potash (K_2O) content of the oven-dried tissue were 6.16, 6.34, 6.49 and 6.63% respectively for potash/nitrogen ratios of 1:1, 1.5:1, 2:1 and 2.5:1 at the first date of sampling (May 22nd), the differences between means (of 6 plots) being significant at $P=0.05$. Foliage from the treatment having a potash/nitrogen ratio of 1:1 had a potash content significantly lower than from the other three treatments at the second date of sampling (June 20th). No significant differences in nitrogen or phosphate content were found for tissue samples from the four treatments.

TABLE III

THE PROPORTION OF THE TOTAL IRREGULARLY COLOURED FRUIT (GRADE C) SHOWING GREEN OR YELLOW-GREEN AREAS (C1 + C2), AS COMPARED WITH SEVERELY AFFECTED FRUIT HAVING COLOURLESS OR "WAXY" AREAS (C6), IN RELATION TO POSITION IN THE GLASSHOUSE

Date	Plots	% (C1 + C2)	% C6
23rd July	1- 4 Shaded	23	65
	21-24 Exposed	71	10
26th July	1- 4 Shaded	28	63
	21-24 Exposed	86	11
30th July	1- 4 Shaded	34	50
	21-24 Exposed	92	4
2nd August	1- 4 Shaded	76	16
	21-24 Exposed	93	1
7th August	1- 4 Shaded	90	9
	21-24 Exposed	96	1

TABLE IV

PERCENTAGE OF DRY MATTER IN THE FOLIAGE (FIFTH LEAF) OF TOMATO PLANTS ON THE EAST AND WEST SIDES OF THE GLASSHOUSE

22nd May				20th June			
Plot	Dry matter (%)	Plot	Dry matter (%)	Plot	Dry matter (%)	Plot	Dry matter (%)
1	9.06	21	10.86	1	9.30	21	12.09
2	9.24	22	10.66	2	8.76	22	11.25
3	9.15	23	10.62	3	9.48	23	11.10
4	9.01	24	10.25	4	9.83	24	11.25
Mean 1-4	9.12	21-24	10.60	1-4	9.34	21-24	11.42

TABLE V

ANALYSES OF FOLIAGE (FIFTH LEAF) FROM PLANTS ON THE EAST (SHADED) AND WEST (EXPOSED) SIDES OF HOUSE C4

Date	Plots	Nitrogen	Phosphate (P ₂ O ₅)	Potash (K ₂ O)
22nd May		%	%	%
	1- 4 (east)	5.00	0.90	6.32
	21-24 (west)	4.26	0.71	6.06
20th June	1- 4 (east)	5.25	0.74	6.26
	21-24 (west)	4.64	0.54	5.38

NOTE:—Each value is the mean of four plots, expressed on the basis of oven-dried tissue.

Analyses of the leaf samples show differences related to the position of the plants within the glasshouse. Thus the percentage of dry matter in the leaves was higher on the exposed (west) than on the shaded (east) side of the house (Table IV). Expressed on the basis of oven-dried tissue, the percentages of nitrogen, phosphate and potash also show positional effects, being higher on the east (shaded) side than on the west (exposed) side (Table V); the differences largely disappear, however, when recalculated on the basis of the fresh foliage.

In addition to the tissue analyses described above, twenty-four plants (six from each treatment) were used to study the total uptake of nitrogen, phosphate and potash. Two plants from each of plots 1-4 and 21-24 were selected at random at the start of the season, the remaining eight plants being chosen from the eight guard plots at the north and south ends of the house. All leaves, side-shoots and fruit removed from these plants were oven-dried and stored until the end of the season; the tissue and fruit from each plant was then milled separately and analysed. As this work is being repeated in 1958, only a summary of the data for 1957 is presented here. Table VI shows the mean uptake of nitrogen, phosphate and potash per plant for each of the four treatments, together with the uptake per acre at a planting density of 14,200.

TABLE VI
UPTAKE OF NITROGEN, PHOSPHATE AND POTASH BY TOMATO PLANTS
RECEIVING LIQUID FEEDS AT DIFFERENT POTASH/NITROGEN RATIOS

Potash/ nitrogen ratio in liquid feed		Nitrogen (N)		Phosphate (P_2O_5)		Potash (K_2O)	
		Uptake per plant*	Uptake per acre	Uptake per plant*	Uptake per acre	Uptake per plant*	Uptake per acre
1:1	Tissue	<i>g.</i> 6.66	<i>lb.</i> 208	<i>g.</i> 1.19	<i>lb.</i> 37	<i>g.</i> 9.34	<i>lb.</i> 292
	Fruit	8.65	271	2.03	64	17.88	560
	Tissue + fruit	15.31	479	3.22	101	27.22	852
1.5:1	Tissue	6.82	214	1.25	39	11.83	371
	Fruit	8.84	277	2.15	67	22.03	690
	Tissue + fruit	15.66	491	3.40	106	33.86	1061
2:1	Tissue	6.67	209	1.12	35	12.13	380
	Fruit	8.42	264	1.98	62	18.51	580
	Tissue + fruit	15.09	473	3.10	97	30.64	960
2.5:1	Tissue	6.51	204	1.22	38	12.26	384
	Fruit	7.74	242	1.99	62	18.63	583
	Tissue + fruit	14.25	446	3.21	100	30.89	967

* Each value is the mean of six plants.

The uptake of potash by the fruit and by the whole plants was significantly higher at a potash/nitrogen ratio of 1.5:1 in the liquid feed (treatment B) than in the other three treatments. Differences in the uptake of potash (K_2O) by the vegetative portions of the plant just failed to attain significance at $P=0.05$ (F test: required 4.76, found 4.68). No significant differences were found in the mean uptake of nitrogen or phosphate.

The total uptake of nitrogen and potash was related to the position of the plants in the glasshouse. Thus significantly more potash and nitrogen was taken up by the plants on the west (exposed) side than on the east (shaded) side (Table VII). The total uptake of phosphate appeared to be unrelated to position.

TABLE VII
TOTAL UPTAKE OF NITROGEN, PHOSPHATE AND POTASH BY PLANTS ON
THE EAST (SHADED) AND WEST (EXPOSED) SIDES OF HOUSE C4

Position	Total nitrogen (N) uptake	Total phosphate (P_2O_5) uptake	Total potash (K_2O) uptake
	<i>g.</i>	<i>g.</i>	<i>g.</i>
Plots 1-4 (east)	13.31	3.16	27.50
Plots 21-24 (west)	16.97	3.25	34.14

NOTE:—Each value is the mean of four plants. The nitrogen and potash values for the east and west sides of the house are significantly different at $P=0.01$.

At a planting density of 14,200 plants per acre, treatments A, B, C and D received in the liquid feeds the equivalent of 806, 1210, 1613 and 2016 lb. per acre of potash (K_2O) respectively. The corresponding mean values for total uptake of potash by the plants were 852, 1061, 960 and 967 lb. per acre (Table VI). Thus plants receiving the liquid feed with a potash/nitrogen ratio of 1:1 (treatment A) took up slightly more (6%) potash than was applied in the liquid feed. As the potash/nitrogen ratio in the liquid feed increased, however, the proportion taken up by the crop decreased, the uptake of potash corresponding to 88, 60 and 48% of the total quantities applied in treatments B, C and D respectively.

At the end of the season soil samples were taken with an auger from the 16 plots (Blocks II-V) situated along the middle of the house. Each plot was represented by two sets of samples, one set taken in the positions of the trickle nozzles and the other mid-way between nozzles along the irrigation lines. Analyses of "available" potash (% K_2O) were made on all samples, the extractant being 0.5N-acetic acid at an acid/soil ratio of 40:1. The results are given in Table VIII.

The content of available potash in the soil close to the trickle nozzles increased markedly with the potash/nitrogen ratio of the liquid feeds, reaching high values at the two highest concentrations of potash in the feeds. Between the nozzles, however, the potash content of the soil remained relatively low. The results indicate very steep gradients in the levels of soil potash, since the "between nozzle" samples were taken only $7\frac{1}{2}$ inches from the nozzle positions, within which distance the mean potash content in one treatment ranged from 0.021 to 0.127%. The results of soil analyses in relation to the position of trickle nozzles will be further discussed in subsequent reports, but it may be noted that the highest concentrations of soluble salts at the end of the growing season, as determined by measurements of electrical conductivity at a water/soil ratio of 2.5:1, were found between the nozzles rather than directly below them.

TABLE VIII

"AVAILABLE" POTASH* (% K₂O) IN SOIL SAMPLES TAKEN AT THE END OF 1957 FROM 16 PLOTS RECEIVING DIFFERENT CONCENTRATIONS OF POTASH VIA TRICKLE NOZZLES

Sampled at the nozzles				
Ratio K ₂ O/N	1:1	1.5:1	2:1	2.5:1
Block II	0.056	0.090	0.107	0.122
III	0.064	0.047	0.108	0.129
IV	0.057	0.091	0.111	0.130
V	0.058	0.079	0.108	0.128
Mean II-V	0.059	0.077	0.108	0.127
Sampled between nozzles				
Ratio K ₂ O/N	1:1	1.5:1	2:1	2.5:1
Block II	0.012	0.019	0.016	0.020
III	0.017	0.013	0.023	0.025
IV	0.018	0.012	0.015	0.018
V	0.017	0.014	0.046**	0.020
Mean II-V	0.016	0.014	0.018	0.021

* Soluble in 0.5N-acetic acid at an extractant/soil ratio of 40:1.

** Anomalous sample, omitted from the mean.

Summary and conclusions

The first year of the trials has shown that trickle irrigation equipment can be adapted satisfactorily for replicated nutritional trials using numerous small plots. As at present modified the diluters would be suitable for systems having not less than about 100 trickle nozzles for each treatment.

The data obtained during 1957 show an increase in the amounts of good quality fruit (grades A and B) with increasing potash/nitrogen ratio, accompanied by a reduction in the amounts of irregularly coloured fruit (grade C). These results were significant statistically, but the proportion of uniformly coloured fruit was relatively low.

Marked differences were found in the growth of plants along the extreme east (shaded) and west (exposed) sides of the glasshouse, affecting the yields and grading of the fruit and also the composition of the foliage and the total nutrient uptake.

Soil analyses at the end of the season showed that the potassium supplied in nutrient solutions remained localised in the vicinity of the nozzles, whereas the highest concentrations of total soluble salts were found mid-way between nozzles.

The results so far reported are based on one cropping season only, and repetition of the trials will be necessary before definite conclusions can be established.

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8. MAGNESIUM DEFICIENCY IN GLASSHOUSE TOMATOES

by

J. H. L. MESSING, G. E. HOBSON & G. W. WINSOR

Intervinal chlorosis of the foliage arising from a shortage of magnesium is one of the commonest deficiency symptoms encountered among commercial tomato crops. Yellowing of the foliage characteristic of this deficiency first appears among the middle and lower leaves of the plant, and may subsequently become less prominent as the removal of leaves is continued upwards throughout the season. Although the chlorosis is generally described as being intervinal, the chlorotic areas may or may not include the leaf margins (5); in the present investigations the margins of the leaves did not remain green.

Magnesium deficiency can readily be corrected by spraying the plants with a solution of magnesium sulphate; the strength of solution used is commonly 2%, with a wetting agent incorporated, though somewhat weaker solutions (1½%) are sometimes advocated as being fully effective and less likely to cause damage by scorching. Despite the existence of an effective method for correcting magnesium deficiency symptoms, long known and widely advocated, the deficiency is nevertheless still commonly seen. It would appear that, for one reason or another, application of the spray treatment is often unpopular amongst growers. The cost of labour for applying the spray treatment, and shortage of manpower, particularly when the plants are cropping heavily, are among the more obvious disadvantages of this form of treatment.

As an alternative to foliar sprays it would seem logical to avoid magnesium deficiency by raising the level of "available" magnesium in the soil, as would normally be done for a deficiency of any other macro-nutrient. Without attempting to review the literature in any detail at this stage, it may be said that the addition of magnesium compounds to the soil has been examined by workers at Long Ashton (3, 4) and elsewhere; the quantities required to be effective seem relatively high, however, and must therefore constitute yet another possible source of difficulties from high concentrations of soluble salts in glasshouse soils (6).

Apart from questions of the magnesium status of glasshouse soils, there is also the problem of nutrient balance. Thus an unduly high ratio of potassium to magnesium in the soil appears to be undesirable (1, 6), and the possible interaction between calcium and magnesium has also received considerable attention with various crops.

From the start of the present investigation it has been accepted that foliar sprays containing magnesium salts are fully effective for the correction of magnesium deficiency in glasshouse tomatoes, and in addition that some response may be expected to fairly liberal applications of magnesium compounds to the soil. Furthermore, it follows from the acceptance of magnesium as an element essential for plant growth that magnesium deficiency must, if sufficiently acute, markedly affect crop growth; the present stage of these investigations is concerned with magnesium deficiency as widely encountered in soil-grown crops, as distinct from the more extensive effects which can readily be produced in sand culture. The immediate object of the work is to study total crop and fruit quality in relation to visual symptoms of magnesium deficiency, and also to levels of magnesium both in the soil and in the plant. The present results form a progress report on the first year of the glasshouse trials; a minimum of 2-3 years results will be necessary before definite conclusions can be reached, even with the varieties at present being grown in the trials.

The glasshouse trials were started in 1957, and occupy two vinery-type houses (D1 and D2), the plants being set out in the houses on February 20th. Each house was divided into 18 plots, separated by asbestos sheeting to a depth of 6 inches in the soil; the function of the asbestos is to prevent surface wash and to mark out the plots precisely for the addition of fertilisers. Additional guard rows were provided at the north and south ends of the houses. Each plot contained 60 plants, consisting of two double rows each of 20 plants with a further 10 plants adjoining the asbestos at both the north and south ends of the plot. The outermost plants on all four sides of each plot, numbering 28 in all, were regarded as guard rows and were omitted from the recording of the crop.

The six treatments were factorial combinations of two levels of potash with two treatments supplying magnesium together with a third treatment in which no magnesium was applied:—

Treatment A.	“Medium potash”	No added magnesium
B.	„ „	Magnesium added in base and top dressings
C.	„ „	Magnesium applied as foliar spray
D.	“High potash”	No added magnesium
E.	„ „	Magnesium added in base and top dressings
F.	„ „	Magnesium applied as foliar spray.

Each treatment occurred once in each of six blocks, each house being sub-divided into northern, central and southern blocks. For the “high” level of potash in the soil, sulphate of potash was applied as a base dressing at 4 oz. per square yard of border (1.92 oz./sq. yd. expressed as K_2O), and a further 3.83 oz. per square yard of potash K_2O given in top dressings throughout the season, mainly in the form of potassium sulphate. For the “medium” level of potash this nutrient was omitted from the base dressings, but a total of 0.47 oz. of potash (K_2O) per square yard was given in top dressings. In treatments B and E magnesium sulphate was applied at 3 oz. per square yard in the base, with a further 5oz. per square yard in top dressings, the last dressing being given in late July. For treatments C and F the plants were sprayed six times in all (twice in April, three times in May and once in June). The first four sprays were applied at a concentration of 2%, and the last two at $1\frac{1}{2}\%$. Nitrogen and phosphate were applied uniformly throughout all treatments. A system of colour-coding was devised for easy identification of plots receiving the various treatments.

Susceptibility to magnesium deficiency is known to vary from one variety to another, and it was decided to include two varieties in the experiment. Each of the 36 plots was therefore sub-divided into two, the varieties used being “Potentate” and “Immuna”. The latter variety is a Swedish F_1 hybrid for which some degree of resistance to *Cladosporium* is claimed; its inclusion in these trials was based on its reported susceptibility to magnesium deficiency.

As previously stated, each plot contained 60 plants, of which 28 were regarded as guard plants; the remaining 32 plants consisted of 16 plants of each of the two varieties, fruit from which was picked and graded (i.e., from 72 sub-plots) usually twice a week throughout the season. The system of grading applied to individual sub-plots contained four categories, these being as follows:—

Grade A.	Fruit of uniform shape and colour
Grade B.	Fruit of uniform colour but rather less regular in shape than in grade A
Grade C.	Fruit showing irregular colouration of any kind
Grade D.	Any fruit not included in grades A–C, primarily consisting of fruit of highly irregular shape.

In the above arbitrary classification grade A corresponded in size to the Pink, Pink/White and White grades of the Tomato and Cucumber Marketing Board, together with any fruit complying with the present definition but below the lower size limit of the White grade. Similarly grade B corresponded to the Blue and Blue/White grades of the Board, together with the corresponding undersized fruit. Grade C included all fruit to which the terms "blotchy", "waxy" or "greenback" would normally be applied, together with any other obvious irregularity of pigmentation. It should be added that the latter definition was rigorously applied, and that grade C thus included a proportion of fruit which for commercial purposes would have been included in better grades. In addition to this simple classification applied to each of the 72 sub-plots, fruit from plots receiving any one of the six treatments was bulked and subjected to further grading; thus the combined fruit of grade A from a given treatment was sized on a grading machine to correspond to the Pink, Pink/White and White grades of the Tomato and Cucumber Marketing Board, with a further category for undersized fruit. Similarly grade B was sub-divided by hand into Blue, Blue/White and under-sized fruit, and fruit of grade C was further separated into several arbitrary categories of irregular pigmentation.

Results

Soil samples were taken from all 36 plots at the time of planting, and again in April and August, each plot sample consisting of at least 7 borings with an auger to a depth of 9 inches.

Results for "available" potassium (K_2O) in the soil samples, determined in 0.5 N-acetic acid extracts, are summarized in Table I, each value in the body of the Table being the mean based on analyses of the three corresponding plots within a given house.

TABLE I
DETERMINATIONS OF PERCENTAGE "AVAILABLE" POTASH (K_2O) IN
SOIL SAMPLES FROM TREATMENTS A—F AT THREE DATES OF SAMPLING

Treatment			A	B	C	D	E	F
Magnesium			—	Soil	Spray	—	Soil	Spray
Potassium			"Medium"			"High"		
February	House	D1	0.066	0.064	0.067	0.094	0.082	0.098
"	"	D2	0.066	0.063	0.071	0.088	0.096	0.091
April	"	D1	0.058	0.054	0.061	0.085	0.087	0.072
"	"	D2	0.059	0.060	0.060	0.096	0.103	0.100
August	"	D1	0.057	0.055	0.051	0.099	0.092	0.062
"	"	D2	0.056	0.060	0.057	0.095	0.088	0.090
Mean			0.060	0.059	0.061	0.093	0.091	0.086

NOTE:—Each value is the mean for three plots.

The results show that higher levels of potash were in fact maintained in the "high potash" treatments (D–F). None of the potash values could be described as low, however, and no indication of potassium deficiency was to be expected in treatments A–C. Statistical analysis of the data shows no significant differences between blocks.

Results for magnesium in acetic acid extracts of the soil samples are shown in Table II, each value being based on analyses of composite samples representing the three corresponding plots in each house. Treatments involving the application of magnesium sulphate to the soil (B and E) caused considerable increases in the amounts of magnesium extracted by acetic acid, particularly at the second and third dates of sampling.

TABLE II
DETERMINATIONS OF PERCENTAGE "AVAILABLE" MAGNESIUM (MgO)
IN COMPOSITE SOIL SAMPLES FROM TREATMENTS A—F AT THREE DATES
OF SAMPLING

Treatment			A	B	C	D	E	F
Magnesium			—	Soil	Spray	—	Soil	Spray
Potassium			"Medium"			"High"		
February	House	D1	0.017	0.025	0.018	0.015	0.019	0.014
"	"	D2	0.019	0.021	0.014	0.014	0.024	0.014
April	"	D1	0.016	0.028	0.014	0.016	0.026	0.016
"	"	D2	0.018	0.029	0.016	0.018	0.027	0.019
August	"	D1	0.011	0.026	0.013	0.013	0.024	0.013
"	"	D2	0.015	0.026	0.017	0.016	0.021	0.014
Mean			0.016	0.026	0.015	0.015	0.023	0.015

Mean values for soil *pH*, based on determinations for all 36 plots, were 6.3, 6.0 and 6.1 as sampled in February, April and August respectively. Statistical analysis of the data shows no significant differences between treatment means but some differences between blocks; in general, house D1 was more acid than D2. Corresponding mean values for *pC*, measured at a water/soil ratio of 2.5:1, were 2.85, 2.75 and 2.84 in February, April and August, the conventional test thus suggesting a fairly high concentration of soluble salts. As would be expected, somewhat lower *pC* values were found in the "high" than in the "medium" potash plots, the lowest mean values being obtained for treatment E where "high" potash was combined with applications of magnesium sulphate to the soil. Determinations of "available" phosphate showed reasonable uniformity throughout the houses.

The plants grew strongly in the early part of the season, those of variety "Immuna" being particularly vigorous at this stage and making the application of the first top-dressings difficult. An outbreak of virus became very evident during May, this being far more serious in the outside (east) house D1, where it was difficult to prevent the plants from wilting in warm sunny weather. There was no doubt that "Potentate" was far more seriously affected by virus than was "Immuna". By June, the foliage of variety "Immuna" showed the chlorosis typical of magnesium deficiency very clearly where no magnesium was applied, and to a moderate degree even where magnesium sulphate was applied to the soil. Foliar sprays very largely eliminated the deficiency symptoms. "Potentate" showed definite symptoms of the deficiency where no magnesium was applied, though less markedly than "Immuna"; this variety responded more readily to the soil treatment and almost completely to the foliar sprays.

TABLE III
AVERAGE YIELDS OF FRUIT, EXPRESSED IN LB. PER PLANT, FOR INDIVIDUAL PLOTS*

Treatment	A	B	C	D	E	F
Magnesium	---	Soil	Spray	—	Soil	Spray
Potassium		"Medium"			"High"	
Variety	"Potentate"					
"	(D1-6)	8.3 (D1-10)	9.9 (D1-1)	9.5 (D1-4)	9.5 (D1-2)	8.5 (D1-3)
"	(D1-9)	10.0 (D1-14)	7.7 (D1-11)	7.8 (D1-12)	11.4 (D1-8)	10.8 (D1-5)
"	(D1-16)	8.7 (D1-17)	9.7 (D1-15)	8.7 (D1-18)	7.9 (D1-13)	10.7 (D1-7)
"	(D2-2)	8.8 (D2-8)	8.2 (D2-1)	9.0 (D2-4)	9.5 (D2-6)	8.6 (D2-3)
"	(D2-7)	9.1 (D2-15)	8.6 (D2-12)	9.9 (D2-10)	9.9 (D2-11)	8.5 (D2-5)
"	(D2-14)	7.7 (D2-18)	8.1 (D2-13)	7.8 (D2-16)	10.3 (D2-17)	7.8 (D2-9)
Mean	9.7	8.8	8.7	8.8	9.7	9.2
Variety	"Immuna"					
"	(D1-6)	10.1 (D1-10)	12.2 (D1-1)	10.4 (D1-4)	11.4 (D1-2)	11.2 (D1-3)
"	(D1-9)	11.4 (D1-14)	9.3 (D1-11)	8.7 (D1-12)	10.9 (D1-8)	10.9 (D1-5)
"	(D1-16)	10.8 (D1-17)	12.3 (D1-15)	8.7 (D1-18)	8.9 (D1-13)	10.6 (D1-7)
"	(D2-2)	11.6 (D2-8)	8.8 (D2-1)	10.8 (D2-4)	11.1 (D2-6)	9.9 (D2-3)
"	(D2-7)	10.3 (D2-15)	10.5 (D2-12)	10.9 (D2-10)	10.5 (D2-11)	9.6 (D2-5)
"	(D2-14)	9.5 (D2-18)	9.8 (D2-13)	9.8 (D2-16)	9.9 (D2-17)	10.0 (D2-9)
Mean	10.7	10.6	10.5	9.9	10.4	10.4

* Numbers in brackets denote the house and plot.

The mean crop yields for the season, expressed in pounds per plant, are given for individual sub-plots of both varieties in Table III; the yields include fruit picked green at the end of the season. No corrections for plants lost or damaged during the growing season have been applied, although the necessary data for such corrections are available for use subsequently. Mean values for the various treatments show, in every case, higher yields from "Immuna" than from "Potentate". There is some slight indication in the data for both varieties that, in the first season, yields from the "high potash" plots increased where magnesium was applied either as a soil dressing or as a spray, but that the reverse was true in the "medium potash" plots. Preliminary statistical examination of the data shows that differences between treatment means were not significant, however, but differences in yield from the two varieties were very highly significant.

TABLE IV
YIELDS OF FRUIT, EXPRESSED IN LB. PER PLANT, AFTER GRADING
INTO FOUR CATEGORIES A—D AS DEFINED IN THE TEXT, TOGETHER
WITH FRUIT PICKED GREEN AT THE END OF THE SEASON

Variety	Treatment	Grade A	Grade B	Grade C	Grade D	Graded total	Green fruit
"Potentate"	A	1.6	2.3	3.6	1.7	9.2	0.5
	B	1.6	2.2	2.9	1.7	8.3	0.4
	C	1.6	2.0	3.0	1.7	8.2	0.5
	D	1.5	2.0	3.2	1.6	8.3	0.4
	E	2.0	2.1	3.5	1.5	9.2	0.5
	F	1.9	2.1	3.0	1.6	8.7	0.5
"Immuna"	A	3.9	2.1	2.7	1.5	10.2	0.5
	B	4.0	2.3	2.5	1.5	10.2	0.4
	C	3.9	2.0	2.4	1.8	10.1	0.4
	D	4.0	1.9	2.3	1.3	9.6	0.3
	E	4.3	2.1	2.4	1.3	10.0	0.4
	F	4.3	1.9	2.2	1.7	10.1	0.3

The grading of fruit into the categories A—D as already described is summarized in Table IV. Some slight increase is apparent in the mean values for top quality fruit (grade A) where magnesium was applied at the higher level of potash (treatments E and F), but by far the most marked difference was again between varieties. Mean values for total graded fruit, and for green fruit picked at the end of the season, are also included in the Table IV. The contrast between varieties is further emphasized in Table V, where the grading of the fruit is expressed as a percentage of the total graded crop.

Samples of the foliage of both varieties were collected for analysis from all plots in May, and again during June, the fifth leaf below the tops of the plants being selected for this purpose. Determinations of magnesium in the oven-dried leaf tissue were made by the method of Mitchell (2). As an example of the results the analytical data for variety "Potentate" at the first date of sampling are given in Table VI.

The results show considerable variation in magnesium content, ranging from 0.31 to 0.65% MgO on the basis of oven-dry material. The values for blocks 4–6, situated in house D2, were clearly higher than for Blocks 1–3, situated in house D1; this latter result was also found for "Immuna" in May and for both varieties in June. The magnesium content of the leaves was, in general, increased considerably by the spray treatment, and to a lesser extent by the application of magnesium sulphate to the soil.

TABLE V

GRADING OF FRUIT INTO CATEGORIES A—D, EXPRESSED AS
PERCENTAGES OF THE TOTAL GRADED CROP

Variety: "Potentate"		Grading			
		A	B	C	D
"Medium" potash	No magnesium	17.0	24.6	39.2	19.2
	Soil "	18.7	26.4	34.5	20.4
	Spray "	18.7	24.1	37.0	20.2
	Mean	18.1	25.0	36.9	20.0
"High" potash	No magnesium	18.7	23.7	37.3	20.3
	Soil "	22.0	23.6	37.5	16.9
	Spray "	22.5	25.2	34.0	18.3
	Mean	21.1	24.2	36.3	18.4
Variety: "Immuna"		A	B	C	D
"Medium" potash	No magnesium	38.4	20.7	26.3	14.6
	Soil "	39.4	21.9	24.0	14.7
	Spray "	38.7	19.7	24.0	17.6
	Mean	38.8	20.8	24.8	15.6
"High" potash	No magnesium	42.1	20.4	23.3	14.2
	Soil "	42.8	20.7	23.4	13.1
	Spray "	42.3	19.3	21.7	16.7
	Mean	42.4	20.1	22.8	14.7

TABLE VI

THE MAGNESIUM CONTENT (% MgO) OF THE FOLIAGE* OF VARIETY
"POTENTATE" (SAMPLED 10TH MAY, 1957) IN RELATION TO TREAT-
MENTS SUPPLYING MAGNESIUM AND POTASSIUM

Treatment	A	B	C	D	E	F
Magnesium	—	Soil	Spray	—	Soil	Spray
Potassium	"Medium"			"High"		
Block 1	0.44	0.47	0.54	0.31	0.44	0.37
2	0.34	0.41	0.61	0.40	0.47	0.47
3	0.44	0.44	0.50	0.43	0.44	0.50
4	0.49	0.55	0.61	0.52	0.61	0.65
5	0.45	0.42	0.56	0.49	0.53	0.64
6	0.44	0.42	0.56	0.44	0.40	0.56
	0.43	0.45	0.56	0.43	0.48	0.53

* Analyses of the fifth leaf below the tops, expressed on the basis of oven-dried material.

Statistical examination of the results for magnesium content of the foliage in all four sets of samples showed that in no case was there any significant effect of level of soil potash upon the magnesium content of the foliage. Mean values for the magnesium content of leaves of both varieties at both sampling dates are given in Table VII, ignoring differences in levels of soil potassium, together with the significant differences between treatment means. The asterisks in the Table denote treatments which significantly increased the magnesium content of the foliage as compared with that of plants not receiving added magnesium (treatments A and D). The uptake of magnesium where magnesium sulphate was added to the soil was considerably greater at the second date of sampling, at which date it resulted in a higher content of this element in the foliage than did the spray treatments.

TABLE VII
MEAN VALUES FOR MAGNESIUM CONTENT (% mgO) IN THE FOLIAGE OF
VARIETIES "POTENTATE" AND "IMMUNA" DURING MAY AND JUNE (1957)

Variety	Date of sampling	No magnesium	Magnesium in soil	Magnesium spray	Significant difference	
					P = 0.05	P = 0.01
"Potentate"	10/5/57	0.433	0.466	0.547**	0.043	0.058
"Immuna"	13/5/57	0.413	0.468*	0.482**	0.043	0.058
"Potentate"	24/6/57	0.441	0.539**	0.506*	0.055	0.074
"Immuna"	25/6/57	0.459	0.559**	0.507	0.050	0.067

* Significant at P = 0.05

** " " " " P = 0.01

Discussion of results

Since the results now presented cover only the first year of the trials it is not proposed to give a very full discussion of these preliminary data; some of the results, particularly those for the grading of the fruit, still await statistical examination.

The first essential of the trials was certainly realised, namely that well-marked symptoms of magnesium deficiency should occur where no magnesium was applied in the treatments. The degree of chlorosis observed, reaching its maximum in mid-season and subsequently becoming less prominent as "leafing" was continued, would be described as severe for "Immuna" and medium for "Potentate"; no visual effects other than chlorosis of the foliage were observed. There was some indication that, where magnesium was omitted, chlorosis appeared earlier at the higher level of soil potash (treatment D) than at the "medium" level (treatment A), but the difference was soon lost as the symptoms developed.

Statistical examination of the data for total crop yields has shown no significant differences between treatments. Grading of the fruit, as in Table V, also shows relatively little response either to magnesium or to potassium within the first year of the trials. In assessing these results it must again be stressed that the "medium" level of potash in the soil would not be regarded as a deficiency level, in contrast to magnesium, deficiency symptoms of which were widespread except where foliar sprays were applied. The most striking feature of these results is, indeed, that crop yields from "Immuna" were so largely unaffected by the very marked degree of chlorosis observed in the foliage. It can hardly be doubted that the photosynthetic activity of the leaves would be impaired by such widespread chlorosis, and the results might tentatively be interpreted as suggesting that this aspect of the synthetic activities of the plant was not a limiting factor for fruit production under the conditions of this trial.

The experiment showed clearly that foliar sprays containing magnesium are far more effective than soil treatments in maintaining the normal green pigmentation of the leaves. This result was not entirely unexpected, but it is of interest that the analytical data in Table VII show that, at the second date of sampling (in June), the magnesium content of the leaf samples was higher where magnesium was applied to the soil than in the sprayed plots. It is, at first sight, paradoxical that the treatment less effective in controlling chlorosis of the leaves actually caused the greater increase in their magnesium content. One possible explanation of this result is that the leaf samples (5th leaf below the tops) could be described as among the youngest of the fully expanded leaves, whereas marked chlorosis was mainly found in leaves further down the stem. Sampling of foliage at lower levels on the plant had, in fact, purposely been avoided as some leaves at these levels already showed signs of senescence and analytical results seemed therefore likely to be unreliable. In future seasons, however, the magnesium content of these lower leaves will need examination. It is unfortunate that, compared with other macro-nutrients, the determination of magnesium by normal chemical methods tends to be time-consuming and exacting; our knowledge of the magnesium status of soils and crops is, indeed, likely to lag behind that of other major nutrients until equipment for more rapid estimation of magnesium by physical methods become more widely available.

Lastly, though not amongst the original objects of these trials, comparison of crop yields from the two varieties is of interest. Thus the results in Table III show quite clearly that "Immuna" gave a heavier crop than "Potentate"; in only three out of 36 plots in which the two varieties were compared did "Immuna" fail to surpass "Potentate" in this respect, and the result was highly significant statistically. The heavier total crop from "Immuna" also included a heavier early crop; thus mean yields per plant up to the end of June (1957) were 3.63 and 4.54 lb. per plant from "Potentate" and "Immuna", respectively. Even more striking is the fact that, expressed as a percentage of the total graded crop yields, the proportion of top quality fruit (grade A) was twice as high for "Immuna" as for "Potentate". Despite its rather vigorous habit of growth in the early part of the season, and its marked susceptibility to magnesium deficiency, this variety appears to merit further attention in this country, at least in unsteamed soils.

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9. SOME ASPECTS OF THE COMPOST AND CASING LAYER IN RELATION TO FRUITING OF THE CULTIVATED MUSHROOM

by

P. B. FLEGG

A considerable part of the year was occupied in carrying out structural alterations to improve the insulation, ventilation and heating of the existing mushroom house. As a result it was possible to complete only one series of experiments within the year. Meanwhile much of the outstanding analytical work from previous experiments has been completed, and a more detailed consideration of some of those results has been possible.

The experimental procedure, methods of analysis and crop recording were essentially as described in the last report (3). Any modifications which were found necessary will be mentioned in the appropriate place in the text.

Addition of organic nutrients to the casing layer

In view of the promising results already obtained (3) from the addition of milled dried compost to the casing layer a large scale experiment, occupying over 400 sq. ft. of bed, was set up to investigate the possibilities of this type of treatment in commercial practice, and at the same time to obtain more information on the causes of the increased yield. The effect on yield may be due to the alteration of the physical characteristics of the casing layer or to the extra source of nutrients supplied by the milled compost. The treatments in this experiment, designated B.4, consisted of additions of milled compost, equivalent to 0, 3 and 6 oz. dry material to both soil and peat/chalk casing layers, together with additions of 3 and 6 oz. milled peat to the casing soil, the milled peat and compost being moistened before application. This made a total of eight treatments which were replicated in an 8×6 randomized block layout. Cropping details are shown in Table I; in this and in all subsequent tables differences from control means significant at the 5% and 1% levels are indicated by one and two asterisks respectively.

Another experiment, P.10, was designed to extend the study of the effects of additions of sucrose and urea to the casing soil. Experiment P.8 of 1956 had already shown no differences in cropping behaviour when up to 1% carbon as sucrose was added to the soil in conjunction with urea to give C:N ratios of 20:1, 10:1 and 5:1. It was decided to adopt for experiment P.10 a C:N ratio of 10:1, and to add sucrose at rates equivalent to 1%, 2% and 3% carbon in the soil. Nitrogen was added as urea, and phosphorus as di-sodium phosphate to give an N:P ratio of 5:1 in each treatment. For the purpose of the present report the amount of carbon in the urea has been ignored. Each of the three levels of nutrients was applied in three different ways: (i) in one application immediately after casing, (ii) in eight equal weekly portions commencing four weeks after casing, and (iii) in four equal portions commencing eight weeks after casing. Thus all treatments were completed by the eleventh week after casing. The nine treatments were replicated nine times in a 9×9 Latin square, using an 8 in. plant pot as a plot. The main effects of the treatments are given in Table II; there was no significant interaction between levels and time of application.

TABLE I
EXPERIMENT B.4

THE EFFECT ON FRUITING OF MILLED COMPOST AND PEAT ADDED TO THE CASING LAYER

Casing medium	Soil†				Peat and Chalk†				Soil		S. E. of means
Material added to casing layer	Milled compost				Milled compost				Milled peat		
	0	3	6		0	3	6		3	6	
Rate of application (oz. per sq. ft.)											
Days, casing to 1st pinheads	28.3	26.8	25.0		27.5	26.8	28.5		26.8	29.0	± 0.95
Mean yields, lb. per sq. ft. at 10 weeks	1.72	1.86	2.04		1.75	1.76	1.97		1.71	1.79	± 0.11
Mean numbers per sq. ft. at 10 weeks	42.7	44.3	42.1		48.5	48.5	41.9		52.8**	51.2**	± 2.3
Mean weight (oz.) per mushroom at 10 weeks	0.64	0.71	0.77		0.57	0.58	0.75		0.52	0.56	

† The yield increase per plot for each addition of 3oz. of milled compost for these six treatments is 0.13 ± 0.056 lb. sq. ft. ($P < 0.05$)

TABLE II
EXPERIMENT P.10

THE EFFECTS ON CROPPING OF ORGANIC NUTRIENTS ADDED TO THE CASING LAYER (MAIN EFFECTS ONLY)

	Weight (g.) of carbon added per pot at a C:N ratio of 10:1†				Time of addition of nutrients in weeks after casing				S. E. of means
	10	20	30		0	4-11	8-11		
	39.2	38.8	44.0**		51.4	36.0**	34.6**		
Days, casing to 1st pinheads	250.7	188.9**	156.0**		138.6	20.84**	248.7**		± 1.07
Mean yields, g. per pot at 8 weeks	14.8	10.5**	8.7**		6.48	11.48**	16.4**		± 10.2
Mean numbers per pot at 8 weeks	17.0	18.0	18.2		20.3	18.2	15.2		± 0.98
Mean weight (g.) per mushroom at 8 weeks									

† Sucrose and urea added as sources of carbon and nitrogen respectively.

Discussion of results

Owing to considerable variation between plots in Experiment B.4 a simple analysis of variance on the basis of treatments and blocks failed to show any significant differences between yields from the various treatments. On considering only the 36 beds from which the effect of adding milled compost to the casing layer can be assessed, however, it was found that the linear component of the treatment sum of squares was significant ($P < 0.05$). The increase in yield per plot for each addition of 3 oz. milled compost was 0.13 oz. of mushrooms per square foot. Thus, as in previous experiments (3), significant increases in yield have been obtained by the addition of milled dried compost to the casing layer. Comparison of the numbers of mushrooms produced by the addition of milled peat and milled compost to the soil suggests that each is exerting a different effect. Milled peat significantly ($P < 0.01$) increased the numbers of mushrooms whereas milled compost did not, and as in earlier experiments the mean weight per mushroom tended to be increased by the addition of milled compost.

That the addition of milled peat had no effect on yield but increased the numbers of mushrooms indicates a physical rather than a nutritional effect. Milled peat added to the soil may be expected to increase the porosity of the casing layer, an effect which has already been shown (1) to affect the numbers of mushrooms produced. Milled compost, on the other hand, did not affect the numbers of mushrooms, but those which formed tended to be heavier. This is suggestive of a nutritional effect. Milled peat and milled compost are somewhat alike in texture, and if a physical effect, only, was involved, a similar response of the mushroom to additions of either material to the casing soil might well be expected. The typical pink-brown colour of compost being colonised by mushroom mycelium was again observed in the casing layer on the plots to which milled compost had been added. The increased yields of heavier mushrooms which have already been produced by the addition of milled compost to the casing layer (3) probably arise, therefore, mainly from the extra source of nutrients supplied.

The delay to the start of cropping caused by the addition of dry milled compost to the casing layer, observed in earlier experiments, did not occur in experiment B.4 and it may possibly be significant that in this experiment the milled compost was thoroughly wetted before application.

Although in a previous experiment, P.8, the addition of sucrose-urea-phosphate mixtures had delayed the appearance of pinheads, no significant effect on cropping was found. In experiment P.10 the amounts of nutrients added were much greater, and the higher levels of added nutrients delayed fruiting and reduced both yield and numbers of mushrooms, but the mean weight per mushroom was unaffected. The time and rate of application also affected fruiting, presumably because of the adverse effect of the added nutrients. Thus pots which were treated at a late stage were less affected than those treated immediately after casing (treatment i).

The adverse effects of the nutrients cannot be directly related to the presence of high levels of nutrients in the casing soil. While in the previous experiment, P.8, little trouble was experienced from extraneous moulds, the higher levels of added nutrients in experiment P.10 caused a dense growth of moulds on many of the pots; the adverse effect on mushroom cropping is assumed to be largely attributable to this.

Conclusions

As described in the previous annual report (3) the aim of the present investigation of the nutritional aspects of the casing layer is to gain more information on the function of this layer and to re-examine the hypothesis which attributes its function in initiating fruiting to the marked differences in nutritional status between the compost and the casing layer. It was tentatively

concluded in the last report that the results obtained did not support this hypothesis. Recent work by Schisler (5) confirms this view. A most interesting result of his work was the production of a normal crop using milled compost only as a casing medium. It seems reasonable to conclude, therefore, that this hypothesis, of many years standing, can at last be finally discarded.

The nutritional aspects of the casing layer are still of interest, however. The practical possibilities of increasing yields by the addition of compost to the casing layer have been discussed elsewhere (4), and they are being further investigated in conjunction with the N.A.A.S. Experimental Horticulture Station at Stockbridge House, near Cawood, Yorkshire. The weight of evidence so far suggests that increases in yield due to the addition of milled compost to the casing layer are mainly due to the additional source of nutrient supplied by the added compost which, as shown in the last report, may be utilised more efficiently for sporophore production than the compost below the casing layer.

The effect of salts in the compost and casing layer

An experiment, P.11, was designed to obtain more information on the way in which additions of salts to the casing layer affect the numbers and yield of mushrooms. By adding four different salts, sodium, calcium and magnesium chlorides, and sodium sulphate, to the casing soil, each at two levels, 200 and 400 milli-equivalents per plot, it was hoped to discover whether the effects were related to salt concentration as such or whether some salts had a more specific effect. Unfortunately the levels of application were apparently excessive, and many pots failed to fruit, although higher levels had been applied in previous experiments without such a disastrous effect.

In view of the marked effect of the addition of sodium sulphate to the compost which was described in the previous report, it was considered desirable to obtain information on the level of soluble salts in a range of composts used commercially. Samples of compost, covering a fairly wide range of composting methods and materials, were obtained from ten growers. The samples were taken at the end of peak heating and forwarded to the Institute for analysis. The results are given in Table III. It was found that the usual water:solid ratio of 2.5:1 was not high enough for satisfactory *pC* readings and a ratio of 5:1 was therefore adopted, the *pC* measurements being made on the dried composts.

In order to obtain information on the effect of salt concentration on mycelial growth in pure culture preliminary experiments have been carried out in conjunction with Miss D. G. Gandy of the Plant Pathology Department.

The following nutrient mixture was added to 1 litre of 2% malt agar:—

Glucose	10 g.
Asparagine	1 g.
MgSO ₄ ·7H ₂ O	0.5 g.
K ₂ HPO ₄	0.25 g.
CaCl ₂	0.2 g.

The mycelium was grown in petri dishes on this medium, to which several levels of salt were added. Sodium sulphate at 0, 0.25, 0.5, 1.0, 2.5 and 5 g. per 100 ml. of nutrient medium was used in two experiments, and in a further experiment three salts, sodium sulphate, sodium chloride and calcium chloride, were added at 0, 1 and 2 g. per 100 ml. The experiments were carried out in an incubator at 25°C.

TABLE III

SOLUBLE SALT CONTENT AND *pC* OF COMPOSTS FROM MUSHROOM FARMS

Sample no.	Type of compost	Composting period	Peak heating period	Soluble salts	<i>pC</i> †
		days	days	%	
1	Medium horse + activators	14	5	5.63	1.97
2	Medium horse + poultry manure	8	2½	7.45	2.03
3	Racing stable + poultry manure	14	4	6.42	2.02
4	Medium horse + poultry and activators	20	not stated	8.32	1.88
5	M.R.A. synthetic	not stated	not stated	14.74	1.93
6	Riding stable manure	13	not stated	7.47	1.94
7	Light horse manure + activators	9	2—3	6.61	2.05
8	Heavy horse manure + activators	9	2—3	6.15	2.12
9	Medium racing stable + activators	11	1½	4.86	2.14
10	Racing stable + poultry manure	8	3	7.32	1.96
11	Unknown from, U.S.A.	not stated	not stated	7.20	—

† Determined at a water:compost ratio of 5:1

In order to investigate further the part played by mushroom mycelium in the movement of salts from the compost into the casing layer analyses have been carried out on both compost and casing layer from spawned and unspawned pots. Samples were taken at filling, casing, and at the end of the experiment, and the results are recorded in Table IV.

TABLE IV

SOLUBLE SALT CONTENT AND *pC* OF COMPOST AND CASING SOIL FROM SPAWNED AND UNSPAWNED POTS

	Soluble salts	<i>pC</i> †
	%	
Soil at casing	0.07	3.50
Soil from spawned pots at emptying	0.30	2.99
Soil from unspawned pots at emptying	0.49	2.76
Compost at filling	6.26	2.22
Compost from spawned pots at emptying	9.43	2.23
Compost from unspawned pots at emptying	11.64	2.02

† Determined at a water: soil ratio of 2.5:1 and a water:compost ratio of 5:1

The practical aspects of improving the mean weight per mushroom and reducing the labour required for picking by the addition of salts to the casing layer are being investigated in conjunction with the N.A.A.S. Experimental Horticulture Station at Stockbridge House.

Discussion

Such results as were obtained from experiment P.11 suggest that at the lower level of application there were differences in the extent to which fruiting was delayed by the various inorganic salts. Sodium chloride delayed the appearance of pinheads much more than did calcium and magnesium chloride or sodium sulphate. Further experiments are required, however, before definite conclusions can be drawn.

Water relationships in the casing layer are undoubtedly of great importance (2), and the addition of salts will increase the total moisture stress within the layer. It is therefore of considerable interest to discover to what extent the very marked effects on fruiting of the addition of salts to the casing layer are due to their effect on moisture stress, and whether some salts have a more specific effect. Work on this important aspect of the function of the casing layer is being continued.

Although not strictly comparable with pC measurements on soils at a water:solid ratio of 2.5:1 it is obvious from Table III that the pC values of the composts obtained from growers are very low. The amount of soluble salt extracted varied from about 5% to 8%, with one very high value of nearly 15%. A few measurements reported last year ranged from 2% to 7%. The soluble salt values for composts may be inflated owing to the extraction of calcium sulphate in excess of that normally in solution in the compost, but the low pC values indicate the presence of other more highly ionised salts and are probably a more reliable guide to relative salinity.

From Table IV it can be seen that during the cropping period the concentration of soluble salts increases considerably as the decomposition of the compost proceeds. It seems, therefore, that the medium in which the mushroom mycelium grows and obtains the major proportion of nutrients is one of relatively high soluble salt content, and that the osmotic pressure of the liquid phase of the medium must also be high. The casing layer, on the other hand, whether soil or a peat/chalk mixture, normally has a much lower soluble salt content, usually well below 1%, with pC values of 2.8 to 3.5 (see Table IV). The concentration of soluble salts found in peat/chalk mixtures is somewhat higher than that in soil, though still less than 1%. This can be offset by the large difference in bulk and the greater water holding capacity of peat mixtures. The pC values so far obtained from peat/chalk mixtures as used in commercial practice, determined with a water:solid ratio of 5:1, have never been less than 3.0. The moisture stress in the casing layer must therefore be much lower than in the compost, and most of the water present in a normal casing layer is probably readily available to the mycelium. Whether the change from a medium of high salt content and moisture stress to one of relatively low moisture stress has any influence on the initiation of fruiting has yet to be established. Even allowing for differences in bulk between compost and casing material it is surprising that the mycelium which grows well in compost at a pC value of about 2.0 or less is so markedly affected in its ability to fruit by the addition of relatively small quantities of soluble salts to the casing layer. It may be that a high salt content can be tolerated during the vegetative stages of growth, but that for fruiting, when large quantities of tissue of high water content are produced, a medium of lower salt content and moisture stress is necessary.

The preliminary experiments on the effects of salt concentration in agar cultures showed that the mycelium can tolerate a certain amount of soluble salts in the medium. Using colony diameter as a measure of growth, concentrations up to 0.5% sodium sulphate had no effect, and

even up to 1% the amount of growth was about 90% of that in the untreated petri dishes. At the 2.5% and 5% levels of sodium sulphate, however, a progressive reduction of growth resulted. At the 5% level, growth was 40% of that of the untreated dishes. When sodium sulphate, sodium chloride and calcium chloride were compared, the 1% level of each had little effect on mycelial growth; in no case was it less than 93% of that on the untreated dishes. At the 2% levels, however, a marked decrease in growth was observed. No differences between the effects of the three salts could be detected.

Evidence was presented in the report for 1956 (3) to show that considerable movement of salts can take place from the compost into the casing layer. The cause of this has now been investigated by comparing the accumulation of salts in the casing layer above both spawned and unspawned pots. Table IV shows the soluble salt content and *pC* values of the casing soil and compost taken from these pots at the end of the experiment, some fifteen weeks or more after casing. The soluble salt content of the soil increased from 0.07% at casing to 0.30% and 0.49% in the spawned and unspawned pots respectively. Corresponding decreases in *pC* were also found. It is obvious that salt accumulation in the casing layer is not dependent upon the presence of mushroom mycelium. This suggests very strongly that the movement of salts is due to physical processes, such as continuous evaporation at the surface of the casing layer resulting in the upward movement of moisture containing dissolved materials, probably combined with diffusion of salts from the compost into the casing layer. The main factors that can be expected to influence the movement of salts into the casing layer are thus the rate of evaporation of water from the casing layer and the extent of the difference in salt concentration between compost and casing later. In experiment P.7 of 1956, the amount of salt which accumulated in the casing soil was correspondingly higher where salts had been added to the compost. This is shown in Table VIII of the report for that year.

The amount of soluble salt found in the casing layer at the end of cropping has been found to range from 0.3% to 0.5%, which represents a considerable increase over that found at casing. The results from experiment P.1 (3) indicate that about 0.5% of soluble salt present at casing delayed cropping slightly and reduced the number of mushrooms per pot; no effect on total yield was found, however. It is not yet possible to decide whether the rise in the concentration of soluble salts in the casing layer throughout the cropping period has any significant effect upon cropping under normal growing conditions. The modern tendency to crop for shorter periods may reduce what effect there may be, but the matter must be investigated in order to obtain a proper understanding of the characteristics of the media in which the mushroom grows and to form a proper basis on which to determine the functions of the compost and casing layer.

Conclusions

1. It has been established that mushroom compost normally contains considerable quantities of soluble salts, rising to even higher concentrations at the end of cropping. The *pC* measurements, using a water:solid ratio of 5:1, show values within the range 2.2 to 1.9 with a corresponding decrease during cropping.

2. The casing layer, either soil or peat/chalk mixtures, has a lower content of soluble salts, usually much less than 1%, and *pC* readings at a water:solid ratio of 2.5:1 are usually not less than 2.8.

3. Movement of salts from the compost into the casing layer takes place irrespective of the presence of mushroom mycelium and seems, therefore, to be a result of physical processes.

4. Mycelial growth in pure culture is adversely affected by increased salt concentration and earlier work has shown that the addition of salts to the casing soil at concentrations similar to those found in the casing layer at the end of cropping delays cropping and reduces the number of mushrooms formed. It is not yet definitely established, however, that the quantities of salts normally occurring in the compost and casing layer are of practical significance under normal growing conditions.

5. There is insufficient evidence as yet to show whether the difference in salt concentrations and related moisture stress between the compost and casing layer is directly connected with the initiation and development of sporophores.

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IV. PLANT BREEDING

by

L. A. DARBY

Tomato

In the tomato crop a greater potential improvement lies in the prevention of wastage due to disease or low quality fruit, rather than in attempts to increase yield by recombining primary yield characteristics. A further advantage may be achieved by modifying the plant habit in order to permit an increase in the number of plants per unit area, or a reduction in the labour requirements for each plant. Such improvements could result in higher yields per unit area, lower production costs and a higher financial return for a given crop weight due to improved quality.

At present it is not possible to undertake any work on disease resistance owing to the lack of staff and facilities, but breeding projects have been started which aim to improve several other specific characters. These affect plant habit and fruit quality in terms of size, shape and colour. In the course of this work close attention is being paid to the retention of the early and total cropping capacity of the existing commercial varieties.

During the year replicated trials of F_1 hybrids were conducted at the Institute, and through the co-operation of the respective Directors observation trials were also organized at the Efford, Fairfield and Stockbridge House Experimental Horticulture Stations of the National Agricultural Advisory Service.

Plant habit

A major criticism of the F_1 hybrids introduced in recent years has been their excessive vegetative vigour, especially when grown early in steamed soils. An attempt is being made to avoid this trouble by modifying varieties of known good combining ability so that they have a more compact habit with shorter internodes and leaves. F_1 hybrids derived from these varieties would also have compact habit.

In a back-cross programme the recessive gene which determines compact habit is being transferred from "Baby Lea" into several other commercial varieties. Simultaneously, new true-breeding genotypes are being selected from this breeding material in order to combine compact habit with the better fruit quality of some of the stronger growing varieties.

Truss size

A major criticism of the widely-grown variety "Potentate" is that its fruit, especially on the lower trusses, is too large and results in many "Blues" when graded. For the bottom truss to give an equal crop weight but with more fruit in the "Pink" and "Pink and White" grades, it would be necessary to have a greater number of fruit. Truss size can be influenced by temperature at the time of truss differentiation, but the lower temperature necessary to induce an increase in flower number may result in fruits of poor shape. Truss size can also be influenced genetically, and the value of recessive alleles which control this character is being investigated. Initially it is necessary to introduce these genes into the genetic backgrounds of present commercial varieties, and a programme to achieve this has been started.

Fruit shape

The use of F_1 hybrid tomatoes offers opportunity for the exploitation of genotypes in which heterozygosity at particular loci gives desirable phenotypes due to incomplete dominance. In order to investigate this further it is necessary to combine the appropriate recessive allele with the genotypes of commercial varieties, so that heterozygotes of potentially useful agronomic type can be produced and tested.

Crosses were made in 1957 to initiate such a programme with alleles determining fruit shape. Heterozygous plants bear almost spherical fruit with an attractive upstanding calyx.

Fruit colour

The occurrence of non-uniformly coloured fruit usually leads to considerable financial loss in tomato crops, and this is particularly so when certain popular varieties are grown. All of the English varieties suffer in some form or other, and to a greater or lesser extent, from these abnormalities, though the reasons for these differences are not clear. Amongst other factors, this intervarietal variability may be due to differences in root size, plant vigour, leaf canopy, truss shape, fruit size or shape, fruit pigment systems, and their interaction with the environment at different times of the year. Data are being accumulated on the relative importance of some of these factors, and the genetic control of the fruit pigment system is being investigated.

The biochemical pathways by which the fruit pigments are produced appear to be particularly sensitive to local environmental deviations, so that the full sequence of pigment production is often blocked and non-uniform colouration results. There are numerous mutant alleles which affect the production of pigments and modify their quality, quantity and distribution in the fruit, and some of these genotypes result in fruit which is of similar colour to the abnormal areas of non-uniformly coloured fruit.

These alleles are being introduced singly into lines of "Potentate", a variety which is very prone to produce non-uniformly coloured fruit, and also into lines of "Ailsa Craig", a variety with different agronomic characteristics in which the fruit is less liable to suffer pigmentation disorders. Within the limits of the back-cross technique, it will then be possible to compare the effects of these alleles both in the same, and also in different genetic backgrounds. These lines, and combinations of them, will then be available for studies of the interaction of genotype and environment in determining the uniformity of colouration, and also for attempts to synthesise new genotypes which, whilst still giving red fruits, might employ a bio-synthetic mechanism which is more stable to environmental variability.

In 1957, ten genetic stocks of different fruit colour mutants were obtained and crossed with "Potentate" and "Ailsa Craig" to initiate the back-cross programme.

Cucumber

F_1 Hybrids

A project has been started to assess the value of the F_1 hybrid breeding method for the production of new varieties of English glasshouse cucumbers. The species is adapted to out-breeding, and when producing seed of the existing varieties it is usual to make sib-pollinations, so a certain level of heterozygosity and heterogeneity might be expected within a variety. It is possible that more favourable expression of some desirable commercial characters might result from genotypes of greater heterozygosity.

The present programme includes:—

- (1) Trials of existing commercial varieties to determine varietal synonymy.
- (2) Production and trials of F_1 hybrids obtained from crossing these partially outbred commercial varieties. These trials should give information on the inheritance of commercial characters in the F_1 generation and also indicate which agronomic types are likely to combine well to give desirable hybrids.
- (3) Production and trials of inbred lines from the existing commercial varieties in order to assess the consequences of inbreeding.

The use of inbred lines would also facilitate parental seed stock maintenance. It is not known on how many plants a cucumber variety should be based in order to prevent any inbreeding depression or genetic divergence in subsequent generations. Therefore, because of the severely limited number of plants which can be grown in a season, it is necessary to obtain seed from an external source each year. This can have many disadvantages. Inbred lines could be maintained at the Institute more easily.

- (4) Production and trials of F_1 hybrids derived from the inbred lines, and comparison of these with F_1 hybrids derived from the original partially outbred commercial varieties, and with the commercial varieties themselves.

In this project, specific attention is being paid to the number and weight of fruit in the early and total crops, and to fruit quality in terms of colour, spines and neck-length.

In the past year several varieties have been inbred for two generations, and a replicated trial of twenty genotypes was conducted. In this trial a total of 29,734 fruits were counted, weighed and graded to commercial standards.

“Pure-breeding” varieties

The cucumber is a semi-luxury product and in order to induce maximum sales, an economic and attractive fruit must be offered. An attempt is being made to improve two existing varieties which are at present widely grown in the industry.

The neck-length of fruits of the variety “Butcher’s Disease Resister” is often variable during the cropping season, and can, if excessive, result in sales resistance in the markets and retail shops. A breeding project aims to improve this variety by stabilising the handle at a short attractive length.

A further programme seeks to increase the spyness of the variety “Telegraph” by selecting from the cross with a very spiny pale green Russian cucumber, “Viroff Salad”,

Triploids

The fruits of an English glasshouse cucumber develop parthenocarpically, and it is undesirable to allow insect pollination. Exclusion of bees from glasshouses or removal of male flowers is an expensive operation, and it has been decided to try and produce triploid plants in which meiotic abnormality should result in male sterility and freedom from pollination risks.

Reciprocal crosses were made in 1957 between diploid and tetraploid varieties, but no viable seeds resulted. The reasons for this failure have not yet been investigated. Search is to be made in all future crops for male-sterile genotypes.

Lettuce

Winter forcing varieties

At present, it is only possible to devote limited time and facilities to the improvement of winter lettuce, and it has been decided, in the first instance, to attempt to produce a variety which will heart as readily as the existing varieties, but which is a lighter and brighter green-colour. The darker colour of the existing widely-grown varieties, suggests a coarse leaf to some would-be purchasers, and this may result in reduced sales or lower financial returns.

Two contrasting methods are to be used in order to attempt to make this improvement. These are:

- (1) An orthodox breeding programme based on inter-varietal hybridization and selection in later generations for desirable recombinant types.
- (2) An induced mutation programme in which seeds are treated with atomic radiation and favourable genetic changes sought in subsequent progenies.

In the winter of 1956/7, 37 lettuce varieties were grown in a heated trial. These included recognised forcing varieties, frame varieties, and various light green summer varieties. The trial revealed the main characteristics of the different varieties, enabled the detection of some synonyms, and facilitated the selection of favourable parental material for the hybridisation programme. These varieties were also grown in an observation trial in Lancashire through the co-operation of Mr. G. F. Sheard, Director of the N.A.A.S. Experimental Horticulture Station, Fairfield. Lancashire is the main area for winter lettuce production under heated glass, and all trials are to be duplicated at Fairfield so that selections may be made under local conditions.

During the summer, plants of "Cheshunt 5B" were crossed with "Forcing Mildew Resisting", or with "Avalanche". "Forcing Mildew Resisting" is of attractive colour, but takes longer to heart than "Cheshunt 5B", and "Avalanche" is a summer hearting variety with a light green colour.

In the autumn, seeds of "Cheshunt 5B" were treated with various atomic radiations through the co-operation of Dr. H. J. M. Bowen, Isotope Division, Wantage Radiation Laboratory. The R_1 generation will be grown in the winter of 1957/8.

In March, Mr. J. A. Haywood of the N.A.A.S. kindly arranged a visit to several lettuce growers in Lancashire, when various problems were discussed and many crops inspected. Thanks are also due to Mr. L. E. Watts of the National Vegetable Research Station who has supplied seed and much advice based on his experience with summer lettuce varieties at Wellesbourne.

V. PLANT PATHOLOGY

1. DIDYMELLA STEM ROT

by

P. H. WILLIAMS

As the special research glasshouse for pathological work was not ready it was not possible to carry out any extensive experiments with plants because of the risk of infection being carried into the trial glasshouses. It is possible that, as at Cheshunt, the disease will not spread on the Institute's nursery even if a small number of plants become infected by airborne spores but, since the disease has not yet occurred in the trial houses, it seemed best to avoid any risk of introducing it. Later in the season, space was available in house X and some small scale experiments were carried out there.

The effect of 2:4:6-trichlorophenoxyacetic acid on infection by *D. lycopersici*

It has been reported by Croxall, Norman and Gwynne (1) that 2:4:6-trichlorophenoxyacetic acid (2,4,6-T), when applied to the soil or to the foliage, increased the susceptibility of tomato plants to *Didymella* Stem Rot. This may be of value in speeding up experiments on the viability of *D. lycopersici* in soil and, accordingly, tests of this substance were made.

Ten tomato plants, in 3-inch pots, were each watered with 50 ml. of a solution containing 125 p.p.m. 2,4,6-T. Ten controls each received 50 ml. of distilled water. A week later all were potted into 6-inch pots, and five days later 50 ml. of a spore suspension of *D. lycopersici* from a pure culture were poured around the collars of each plant. By this time the treated plants were showing the effects of the hormone, the young leaves developing typical "fern leaf" symptoms.

The first infected plant was found twenty days after inoculation, and the experiment was continued for a further sixty days. Table I shows that diseased plants continued to appear over the whole of that period and that the disease was rather quicker in developing in the untreated plants.

In a second experiment thirty plants, potted into 6-inch pots at the same time as the above, were allowed to grow for ten days before treatment. Ten were then treated with 100 ml. each of a solution of 125 p.p.m. 2,4,6-T and ten with 100 ml. of a 62.5 p.p.m. solution. There were ten controls. Fifteen days later each plant was inoculated by pouring 50 ml. of a spore suspension around the base of the stem. Some plants were then beginning to show the effects of the hormone.

TABLE I
NUMBER OF PLANTS OUT OF TEN SHOWING LESIONS AFTER TREATMENT
WITH 125 p.p.m 2, 4, 6-T

Days after inoculation	Untreated	Treated
20	1	0
21	3	0
28	3	1
38	4	1
64	6	4
69	6	6
73	6	7
80	9	7

Infection was slow to develop, and only a few plants became infected. During the sixty days following inoculation three control plants developed the disease, the numbers infected among those receiving 62.5 and 125 p.p.m. 2,4,6-T being four and three respectively.

These results are contrary to those previously reported and require further confirmation.

Penetration of roots by *D. lycopersici*

It has been shown (3) that *D. lycopersici* can penetrate a tomato stem for distances up to 15 cm. beyond the limits of visible lesions. No evidence exists, however, as to whether the fungus can spread from an infected stem into the roots. If this were so to any extent there would be a considerable risk of a large quantity of infective material being left behind when a diseased plant was removed.

Tomato plants growing in 9-inch pots were inoculated by placing a piece of culture in contact with a wound made by removing the lowest leaf. Three weeks later, when lesions had developed on the stems, two plants were removed from their pots and the roots washed free from soil. Isolations were made from them by sterilizing pieces of root about half an inch in length in calcium hypochlorite solution and placing them on slopes of Dox agar. Pieces of root for isolations were taken close to their origin and two inches and four inches further away from the stem. Of nine pieces taken close to the stem, two were found to be infected. None of those taken from further away from the stem was infected.

Thirty-five days after inoculation the remaining plants had wilted and further isolations were made from the roots. In this case three out of ten isolations from close to the stem were positive but *D. lycopersici* was again absent from those made from further away.

This experiment, while on a small scale, suggests that *D. lycopersici* does not readily invade roots from infected stems. It confirms observations made at Cheshunt where the disease was absent in plots where it had been severe the previous the previous year. When the fungus has been found on roots it is probable that they have been directly invaded by the fungus.

Antagonism to *D. lycopersici* in the soil

It has been previously shown that spores added to unsterilized soil rapidly die, but when they are added to autoclaved or partially sterilized soil they germinate and the fungus grows readily and may form pycnidia. The cause of the death of the spores appears to be biological, and may be due to the presence of a substance toxic to them or merely to competition for nutrients from other soil organisms. In previous experiments a number of organisms which did not show antagonism to *D. lycopersici* *in vitro* were grown in autoclaved soil for varying periods. The soil was then inoculated with spores of *D. lycopersici* and plated after a further incubation period. None of the organisms tested, either alone or in combination, produced any effect on the growth of *D. lycopersici* in the soil. On the other hand, the addition of a small quantity of unsterilized soil or of a soil suspension soon rendered the sterilized soil unfit for colonisation by *D. lycopersici*.

The results of these experiments suggest that competition for nutrients is not the cause of the failure of *D. lycopersici* to become established in unsterilized soil but that it is due to the presence of organisms antagonistic to it. The presence of such organisms in glasshouse soils has already been demonstrated (2).

As a preliminary to tests with organisms antagonistic to *D. lycopersici*, samples of soil from house D2 were plated on suitable media and colonies of fungi, actinomycetes and bacteria picked off at random. The resulting cultures were tested for power to inhibit the growth of *D. lycopersici* by inoculating plates of Dox agar at opposite sides with both organisms. The growth of each organism was measured daily along the line joining the centres of the colonies, the production of an antibiotic substance being shown by the cessation of growth by the colony of *D. lycopersici*. The distance between the two colonies when growth of *D. lycopersici* ceases gives a rough measure of the power of the inhibitory substance produced by the test organism. Two isolates of *D. lycopersici* were used, and tests were repeated when necessary. The results are given in Table II.

TABLE II

EFFECT OF CERTAIN SOIL FUNGI ON THE GROWTH OF *D. lycopersici*
in vitro

Test organism	Number of strains tested	Zone of inhibition
<i>Penicillium</i> A	1	mm. 268
" B	1	Slight
" C	5	None to 17
" D	6	? to 15
" E	3	9 to 23
" F	1	2 to 3
" G	2	None or ?
" H	1	None
" I	1	25
" J	2	9 to 16
" K	1	None
" L	1	2
" M	1	1
<i>Pyrenochaeta</i> sp.	3	None to slight
<i>Trichoderma</i> sp.	5	? or slight
<i>Acremonium</i> sp.	1	None
<i>Mucor</i> sp.	1	None
<i>Fusarium</i> spp.	2	Slight to 9
Sterile	4	Slight to 5

As might be expected the degree of inhibition varied considerably even between isolates of what appeared to be the same organism. Where the zone of inhibition was clear, its width is given in millimetres in Table II. In other cases, the colony of *D. lycopersici* continued to grow but at a reduced rate and the margin of the colony nearest the test organism became flattened or even slightly concave. Eventually the two colonies met, but it was evident that some substance had been produced by the test organism which had a small inhibitory effect on the growth of *D. lycopersici*. Such cases are designated "slight" in the Table. In a third category are a few cases where the colony of *D. lycopersici* became flattened but did not stop growing because the test organism grew rapidly and reached the margin of the colony of *D. lycopersici* before the inhibitory substance could take effect. These are marked by a "?" in Table II.

In Table II only fungi are listed. Of five actinomycetes tested only two inhibited growth, while only one bacterial isolate of thirty-two tested appeared to have any effect on the growth of *D. lycopersici*, the colony becoming flattened in one plate.

Certain of these organisms are now being grown in soil in order to test their ability to render it unsuitable for colonisation by *D. lycopersici*.

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2. CUCUMBER MILDEW

by

OLWEN M. STONE

Experiments were continued along the lines laid down during the previous year.

Resistance to cucumber mildew within the family Cucurbitaceae

Plants of those species which appeared resistant or immune to cucumber mildew in the glasshouse during the previous year's experiments were grown in the cucumber houses for further testing. The following list shows the species retested.

<i>Benincasa cerifera</i>	<i>Ecballium elaterium</i>
<i>Bryonopsis laciniosa</i>	<i>Echinocystis lobata</i>
<i>Cucumis africanus</i>	<i>E. wrightii</i>
<i>C. anguria</i>	<i>Luffa acutangula</i>
<i>C. dipsaceus</i>	<i>L. aegyptica</i>
<i>Cyclanthera explodens</i>	<i>Momordica balsamina</i>
<i>C. pedata</i>	<i>M. charantia</i>

Under the more humid conditions of the cucumber house only the two species of *Luffa* and *Ecballium elaterium* were completely free from mildew. All the other species showed some infection on examination, though the number of spores was small and in some cases confined to the midrib (as in the species of *Echinocystis*). In the three species of *Cucumis* tested the infection was marked by the presence of yellow spots on the leaves on which the spores could be seen. This was presumably a host reaction to infection. Although the numbers of spores were small they were as viable as spores from heavier infections and readily infected a standard cucumber variety ("Butcher's Disease Resister"). No further work on this aspect of cucumber mildew is envisaged at present as it appears that the immune species are unlikely to cross readily with cucumber and could not therefore be included in the breeding programme.

Other hosts for cucumber mildew

Cross inoculation experiments this season have been confined to a few hosts that were selected as most promising from the previous year's work, and have been carried out on a larger scale.

Experiments with mildew from *Ranunculus repens* inoculated onto cucumber were carried out in the early part of the year. The first series were moderately successful, showing up to 50% infection in a set of fifty tubes. As the season advanced the percentage infection fell to less than 5%. Sub-culturing of the mildew from these infections onto further seedling cucumbers was not successful. Parallel experiments with mildew from *Sonchus* sp. inoculated onto cucumber gave similar results. For example, in a series carried out in the middle of June, only one plant out of fifty was infected and, in this case, the infection was on a damaged cotyledon. A sub-culture of this infection produced infection again on *Sonchus* but not on cucumber. It therefore seemed necessary to consider more fully the possible factors involved in infection, whether due to the external conditions or to the state of the host. Thus the fact that infections were more readily obtained in the winter months might be due either to the effect of low light intensity on the host or to the slightly lower temperature of the host. It was possible at all times to control the minimum temperature of the experiments, but, in summer, the maximum temperature occasionally rose higher than intended. Furthermore, the single infection on a damaged cotyledon suggests that mechanical injury of the host tissue might lower the resistance of the host to infection. In order

to investigate the effect of light on the infection, a small box was made. This consisted of two racks, each capable of carrying 25 tubes, mounted in a glass-sided box. Four daylight-type vapour lamps were mounted outside the box at a distance of 12 in. from the tubes and at the level of the foliage of the test plants. The whole could be covered with black cloth to exclude light, and the time of illumination was controlled with a time switch. The box was set up in the experimental glasshouse and temperature was kept down as far as possible within the range 50–60°F. The lamps were mounted outside the box containing the tubes in order to keep down the temperature, and the time of illumination was arranged so that the box was illuminated in the hours of darkness and thus did not coincide with the time of highest temperature in the glasshouse. It is hoped that accurate temperature control will be possible in future.

The experiments in which this box is being used are still in progress and the results will be reported later.

A series of inoculations was also carried out on damaged cotyledons of cucumber. The cotyledons were damaged by snapping them close to the stem so that at least some of the vascular tissue was broken, but so that the damaged part remained attached. The inoculation was made on the distal part of the cotyledon. The results were inconclusive and it will be necessary to repeat and modify the experiments.

It seems possible that no single factor will be found to influence infection to a significant degree, but that a combination of factors working together may affect the host susceptibility.

The majority of the year's experiments involved inoculations from other hosts onto cucumber seedlings in tubes, because considerable difficulty was experienced at first in raising sufficient material of the possible alternate hosts in tubes. However, the difficulties were overcome, and experiments were begun on the reverse inoculations on a large scale towards the end of the year. These appear to be proceeding successfully, but since the results are not yet complete they will be reported later.

The identity of the pathogen

At the end of 1956 material of *Sonchus oleraceus* was found in the glasshouses bearing perithecia of *Erysiphe cichoracearum*, and of *Ranunculus repens* with perithecia of *Erysiphe nitida*. Since there were considerable quantities of both a series of experiments was set up to find out whether the perithecia would ripen and produce ascospores, and whether the ascospores were capable of infecting cucumber or the original host. Microscopical examination of the perithecia showed that the spores were formed, and they seemed to be almost ripe in both cases. On *Sonchus* the perithecia were chiefly on the dead stems of the plant, and on *Ranunculus* they were on yellowing leaves. The perithecia were either removed from the leaf or stem and placed directly on the cucumber cotyledon, or else were suspended above the cucumber while still attached to the original stem or leaf. Some were inoculated without previous treatment; others were first placed for 7 to 10 days in the refrigerator ice box at -4°C. The inoculated tubes were kept for three months, but no infection was observed. Parallel experiments using the correct host, i.e., *Sonchus* mildew on *Sonchus*, were set up at the same time, but no infection was observed in these either. It is clear that more experiments are required on the conditions necessary for the release of ascospores before work on the identity of the cucumber mildew is continued on these lines.

Other mildews

No experimental work has been carried out on other mildews this season, but a collection of mildew stocks is being made in order that work will be possible when required. Mildew is now available on Chrysanthemum, Begonia, Cineraria, Michaelmas Daisy and Statice.

3. CARNATION WILTS

by

MARION H. EBBEN

Caryophyllaceae species as alternate hosts for wilt fungi

An experiment was started at the end of 1956 to see whether infection of the soil with wilt fungi produced noticeable disease symptoms in Caryophyllaceous seedlings and plants. Five fungi were used in this experiment, four isolates from carnations, *Verticillium cinerescens*, *Fusarium oxysporum*, *F. roseum*, *F. solani*, and one soil fungus, *Paecilomyces varioti*, which had been commonly found in carnation soils. The fungi were grown in sand/oatmeal cultures, which were then mixed with sterile J.I. seed compost; two control series were used, one with sterile compost only and a second in which a sterile sand/oatmeal culture was mixed with the compost. Seeds of six species of the Caryophyllaceae were sown in the composts, germination and general appearance of the seedlings was recorded, and some of the seedlings were potted on for further observations. The species chosen for this investigation were *Dianthus caryophyllus*, and *D. chinensis* (the two "parents" of the perpetual flowering carnation), *D. barbatus* and *Lychnis chalcedonica*, two garden species, and two common weeds, *Melandrium album* and *Spergula arvensis*. Table I gives the initial results.

TABLE I

GERMINATION AND GROWTH OF CARYOPHYLLACEOUS SPECIES IN ARTIFICIALLY INFECTED SOILS

Composts Species	Compost only	Compost + sand oatmeal	Compost + sand oatmeal cultures of fungi:				
			<i>V. cinerescens</i>	<i>F. oxysporum</i>	<i>F. roseum</i>	<i>F. solani</i>	<i>Paecilomyces varioti</i>
<i>Dianthus caryophyllus</i>	12% ***	44% ***	11% **	12% *	11% *	22% **	25% **
<i>D. chinensis</i>	33% *	33% **	6% *	20% *	20% *	40% ***	40% *
<i>D. barbatus</i>	96% ***	53% **	60% **	40% **	46% **	53% **	40% **
<i>Lychnis chalcedonica</i>	96% **	73% ***	46% **	66% **	26% *	66% *	73% **
<i>Melandrium album</i>	73% **	96% *	66% ***	96% *	73% ***	80% **	73% **
<i>Spergula arvensis</i>	53% **	73% **	53% **	60% **	46% **	60% **	40% **

NOTE:—In the above Table germination is given as percentage, and growth is rated as follows:—
good ***; moderate **; poor*

The germination of the seed of *D. caryophyllus* and *D. chinensis* was very erratic, possibly because of its age, as it came from an outside source. Seed of the other four species was collected during the previous summer and was only between one and two months old.

No definite symptoms appeared on these seedling plants although they were kept for several months. Plants of *M. album* and *L. chalcedonica* were transplanted into a trough of sterile soil

and were finally examined when they were fifteen months old. Some grey discolouration of the pith in *L. chalconica* plants inoculated with *F. roseum* was noticed, but the fungus was not re-isolated. No other symptoms were seen in this species.

The main shoots of *M. album* inoculated with *F. roseum* showed a die-back and pinkish-brown discolouration of the pith, and the fungus was re-isolated from this tissue. The other pathogen which appeared to have established itself in *Melandrium* without producing any marked symptoms was *V. cinerescens*. This was re-isolated from brown tissue in the roots of a plant, although not from discoloured xylem in the stem. *M. album* is a common weed of arable land, and as it can apparently act as a carrier for two pathogenic fungi, might be one of the means whereby these fungi survive in field soil. Infected roots could be present in loam stacks or in the original soil of a glasshouse.

Infection of chrysanthemum plants with carnation slow wilt bacteria

The bacterium associated with slow wilt of carnation has been regarded as a strain of *Erwinia chrysanthemi* (1). An isolate of *Erwinia* from a wilting carnation plant was re-inoculated into young carnation plants to test its pathogenicity, and at the same time two young chrysanthemum plants were also inoculated with this bacterium. Inoculations were made by pushing pieces of sharpened sterilised matchstick, which had been soaked in a bacterial suspension, into the stems of the plants so that the point penetrated the xylem tissue. The pieces of matchstick were left in position in order to mark the point of inoculation. Control plants were similarly treated with sterile matchsticks.

Typical wilt symptoms developed on the carnation plants in 5–7 weeks. No external symptoms developed on the chrysanthemum plants in three months, but when the plants were examined slight browning of the xylem was seen just above the point of inoculation. No xylem discolouration was seen in the control plants. Pieces of surface-sterilised stem taken from near the inoculation point were incubated in broth and the bacteria growing out streaked on potato dextrose agar. Typical colonies of *Erwinia* were isolated from the inoculated carnations and chrysanthemums. Broth tubes prepared from pieces of stem from control plants remained sterile.

Only one strain of the slow wilt bacterium was used in this test, but it is very possible that other strains of the carnation pathogen would vary in their ability to infect and produce symptoms in chrysanthemums. Different isolates of *Erwinia* from wilting carnations can vary slightly in their biochemical reactions, and these differences may correspond with differences in pathogenicity.

The occurrence of disease in the trial glasshouses

The Institute's three glasshouses used for carnation growing on a commercial scale were planted up in the spring of 1955 for the first time. The same plants have been grown continuously until the end of 1957, when they were pulled out. During this three-year cropping period diseased plants were removed, as they occurred, and were examined to determine the cause of disease. At the end of 1957, just before the plants were pulled out, all the beds in houses 1 and 3 were examined and gaps due to diseased plants were recorded. The results of this survey are shown in Tables II and III.

Isolations from a selection of the diseased plants during the three-year period of growth showed that in practically all cases symptoms were due to *Fusarium roseum* (*sensu* Snyder and Hansen). A few isolations of *F. oxysporum* were also made, but *Verticillium cinerescens* was never isolated. Occasional isolates of *Alternaria gypsophilae* and *Chaetomium* spp. were made from diseased tissues, but these fungi did not occur to any great extent.

TABLE II

CARNATION HOUSE 1

DIAGRAM OF BEDS SHOWING VARIETIES AND PERCENTAGE OF
DISEASED PLANTS REMOVED UP TO DECEMBER, 1957

House D4	Northland	27	White Sim	28	House 2
	Midas	6			
	Ashington Pink	14	Sidney Littlefield	29	
			Ashington Pink	22	
	Ashington Pink	10	Ashington Pink	8	
	Northland	15	Ashington Pink	15	
	Northland	13	Ashington Pink	18	
			William Sim	13	
	Northland	13	William Sim	17	

N end of house.

TABLE III

CARNATION HOUSE 3

DIAGRAM OF BEDS SHOWING VARIETIES AND PERCENTAGE OF DISEASED
PLANTS REMOVED UP TO DECEMBER, 1957

House 2	Apollo	12	Crowley's Sim	25	Midas	20	Aphrodite	62
	Heather Pink	15	Johanna Sim	27	Ashington White	22	E. F. Guba	35
	March. of Headfort	22						
	Ashington Pink	18	Northland	37	Kobenhavn	49	Monty's Pink	19
							Aase Thor	26
	Ashington Pink	18	Northland	29	Topsy	21	Aase Thor	43
	Ashington Pink	18	White Sim	11	William Sim	8	Northland	18
	Ashington Pink	10	White Sim	13	William Sim	9	Northland	22
	Ashington Pink	9	White Sim	15	William Sim	13	Northland	18

N end of house

Of the three main varieties grown (Northland, Ashington Pink and William Sim) William Sim seems the least affected by disease, the other Sim variety, White Sim, showing approximately the same amount of disease when grown in a comparable position, e.g., in house 3. The amount of wilt recorded in Northland and Ashington Pink shows wide variation from bed to bed, but there seems to be a tendency for a higher percentage of disease to occur in beds nearer the south end of the houses or on the outside beds of the block. This is noticeable in house 3, where Northland grown on the open west side of the house shows a higher percentage of diseased plants than the same variety in house 1 on the east side which is adjacent to another block of glasshouses. In house 3 the percentage of diseased plants nearer the south end is even higher. Other varieties grown in smaller numbers show varying amounts of disease, Crowley's and Johanna Sim at the south end of house 3 being more diseased than the other Sim varieties. Aphrodite and E.F.Guba

in the same bed in house 3 show widely different disease percentage; presumably the two varieties are not equally susceptible. The highest disease rating in a bed of one variety was in Kobenhavn in which 49% of the plants had been discarded.

Although in several beds a large percentage of plants had been removed, the scatter of the diseased plants was such that no very obvious patches appeared in the crop, the plants adjacent to those removed being easily trained in to fill the gaps.

Experiments with gibberellic acid on carnations

Gibberellic acid is known to increase shoot growth in various plants, and it would be of interest if the number or growth in length of young carnation shoots could be increased using this substance. More cuttings, or longer ones, might be more speedily obtainable from mother plants, and faster plant growth, without any temperature increase, would reduce the possibility of wilt pathogens penetrating the young shoots.

Preliminary experiments were tried with two types of plant, stock plants several months old and young plants about one month old. The stock plants were treated by smearing a paste of lanolin containing 1% gibberellic acid round the base of the stem. Most of the main shoots had been removed from these plants for cuttings, and small axillary shoots were beginning to appear. The application of gibberellic acid did not seem to affect the development of these young shoots, and no changes were noted, after two applications of gibberellic acid, when treated plants were compared with control plants.

The one month old plants were each watered with 10 ml. of a 10 μ gm./ml. solution of gibberellic acid. The shoot lengths from the junction with the main stem to the leaf tips were measured nine and seventeen days after the application of gibberellic acid. Six plants with 24 shoots were treated and measured, and four untreated plants with 24 shoots were examined for comparison. The percentage increase in the shoot length is shown in Table IV.

TABLE IV
INCREASE IN SHOOT LENGTH AFTER TREATMENT WITH GIBBERELIC ACID

	1-9 days	9-17 days
G. A. treated plants	22.7%	7.0%
Controls	16.2%	5.3%

These results suggest that gibberellic acid may be effective in increasing shoot length in carnations, but further work would be needed to determine the best method of application and the stage of plant growth at which the greatest effect would be produced.

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4. MUSHROOM DISEASES

by

DOREEN G. GANDY

The study of La France disease and similar disorders received added impetus during 1957 as a result of outbreaks on commercial farms which reached epidemic proportions during the autumn. A variety of names was used to describe the trouble, of which Brown disease and Watery Stipe were the most popular. In a large number of cases, however, the outbreaks did not differ materially from those previously attributed to La France disease. In the absence of known causes of these outbreaks it has not been possible to determine how many disorders of this type exist; identification has therefore been based upon symptoms observed, hence the multiplicity of names. It is perhaps pertinent to discuss at this point the value of using such symptoms as a basis for the identification of disorders of this type. Almost all the symptoms seen in these recent outbreaks have been previously described for certain other diseases, namely, Mummy disease (5), and Damping-off (6), as well as for La France disease (3). The following is a comparison of these symptoms.

Comparison of symptoms observed in 1957 outbreaks with those described for La France disease (L.F.), Mummy disease (M) and Damping-off (D).

1. Great reduction in crop, largely owing to the non-appearance of mushrooms rather than to the production of unsaleable ones.
L.F. In one case “—no mushrooms appeared at the first break and only a few straggling mushrooms at the second—”.
M. No comment on this point.
D. “—little or no mushroom production had taken place”.
2. Production of good early flushes followed by a rapid decline in cropping and quality.
L.F. “—the first two breaks were normal—. At the time of the third break the whole house succumbed and the beds with both spawns were likewise covered with dead and dying mushrooms”.
M. No comment on this point.
D. “Mushrooms had formed, even to the extent of a good first flush. The crop rapidly degenerated—”.
3. Sporophores with stipes longer and thinner or shorter and thicker than normal; pilei often small.
L.F. (The mushrooms) “had very thin long stipes and globular thin-fleshed caps which had somewhat the appearance of *Coprinus*”.
M. “The first evidence of the development of the mummy disease in a mushroom bed is the appearance, in a circumscribed area, of a few sporophores with stipes longer and smaller in diameter than normal, and often slightly curved; the pilei fail to attain normal diameter and are often in a tilted rakish position, instead of at a right angle to the stipe”.
D. This type of symptom is not described.
4. Death of mushrooms while still immature.
L.F. “—after reaching about half the normal size, all grew no more and died rather soon”.
M. “However, the development of the sporophores ceases very soon. Most of them fail to grow beyond the pinhead stage”.

- D.* "The crop rapidly degenerated into small, withered, brown and under-developed mushrooms".
5. Dying mushrooms turn a putty colour and then may turn brown. Under dry conditions the mushrooms wither and mummify, but under wetter conditions bacterial decay may set in. The stipes of dying mushrooms often have a pithy central cavity, and discolouration usually first appears in the lower half of the stipe.
- L.F.* "They died in a rather soft rot turning slightly brown, but not dark".
- M.* "In the white mushroom varieties the entire sporophore is gray or light tan. The tissues are firm at first, but become slightly more moist externally than normal, finally they become spongy, dry and tough".
- D.* "Rotting generally did not take place, the stunted mushrooms remaining indefinitely on the beds in a mummified condition. —the mushrooms were found to be dry and pithy inside the stipe, of a rubbery texture and, generally, the interior of the stipe was quite brown".
6. The "watery stipe" condition is common. Translucent, waterlogged streaks are seen in the tissues, especially those of the stipe. In extreme cases the whole of the stipe may be waterlogged. The streaks may surround cavities in the tissues. In older specimens bacteria are found in the waterlogged tissues.
- L.F.* No comment on this point.
- M.* "Longitudinal sections through diseased sporophores in the earliest identifiable stages of the mummy disease show colourless, translucent, watersoaked dots or streaks in the white tissues of the stipe and, frequently, of the pileus".
- D.* No comment on this point.
7. Affected sporophores appear to have a smaller number of rhizomorphs than normal, and correlated with this there is frequently a conspicuous development of fluffy mycelium at the base of the sporophore.
- L.F.* No comment on this point.
- M.* "When a diseased mushroom is removed from the bed it is accompanied by a large mass of numerous rhizomorphs and adhering soil. This is especially marked in contrast with the smaller number of rhizomorphs subtending normal sporophores".
- D.* No comment on this point.
8. The tissues may be dry and spongy (in dead mushrooms) or, less frequently, slightly gritty (in living specimens). This latter type is often found in mushrooms with under-developed gills and veils.
- L.F.* "—the mushrooms did not have the corky texture associated with mummy disease".
- M.* "When the stipe of an infected sporophore is cut across with a sharp knife there is a gritty sound and feel as if the stipe contains some granular material".
- D.* "—a rubbery texture—".
9. The rate of spread appears to be variable. In one instance it was about ten feet in six weeks, in other cases the whole of a house was affected very early in the life of the crop.
- L.F.* "In this house the first two breaks were normal on the beds with one kind of spawn, —At the time of the third break the whole house succumbed,—".
- M.* "The disease spreads through the beds at the rate of about one foot per day".
- D.* "It was also noted that "damping-off" often would spread rapidly through a bed—".

10. The mode of transmission is not known, indeed, it has not been established whether the disorder is transmissible or not. More than one disorder of this type may exist and they may behave differently in this respect.
- L.F. "—the investigation has not, so far, revealed either definite conditions or the presence of any foreign organism regularly related to the disease".
- M. "Transmission has been secured by transferring casing soil or compost from affected to normal beds".
- D. "The purpose of the experiment was, however, to prove that the presence of *Fusarium* spp. in the casing soil would give rise to disease symptoms in mushrooms exactly similar to those obtained in cases of "damping-off"; and this end was achieved".

It will be seen from the foregoing that the symptoms observed do not correspond with those described for any one disease, and that almost every symptom seen is common to more than one disease already described. The identification of these diseases rests largely on such variable symptoms as length of stipe, texture of tissues, number of rhizomorphs, colour, and the presence or absence of a wet rot. This overlapping of symptoms demonstrates the very limited range of response to disease and environment possessed by the mushroom. Mummy disease appears to be the most distinctive in this group and was probably not concerned in most of the recent outbreaks, but it is now obvious that many of the symptoms originally described as typical of this disease are by no means restricted to it.

Examination of apparently normal and healthy mushroom sporophores selected at random showed that about 70% of them had watery streaks in the stipes, which indicates that this may not be a reliable symptom in the identification of any of these disorders.

Cropping experiments

It was only possible to carry out one cropping experiment in the mushroom house in 1957. This was a partial repetition of those experiments previously carried out in pots but which had given unsatisfactory results, the object being to determine whether any of these disorders could be transmitted through the mycelium. For this latest experiment beds, each having an area of approximately nine square feet, were used. They were filled with MRA synthetic compost to a depth of nine inches, peak heated, spawned in the normal manner, and cased three weeks later with steam sterilized soil. The casing soil panned badly after watering, and this was found to retard cropping unless the surface was periodically broken up by raking. The spawn was made from mycelial and tissue cultures of mushrooms from abnormal crops on commercial farms. The cultures were the same as those described in the Annual Report for 1956, but with two additional ones: D/1/2, which was a mycelial culture derived from D/1, and H/1, which was isolated from material obtained in Surrey. The yield obtained in this experiment is shown in Table I.

No marked deformities were observed in the sporophores produced by the various spawns. Some died before reaching maturity, but this could not be definitely attributed to La France disease since *Cephalosporium lamellaecola* was isolated from some of them. The most significant aspect of the results was the very low yields of several of the spawns. This great reduction in yield was one of the most serious aspects of the outbreaks on commercial farms in 1957. Yields were frequently a quarter or less of normal.

It is not known what effect mushroom flies had on the results of this experiment. Sciarids were numerous throughout the period, and insecticides could not be used frequently without interfering with the Entomology Department's investigations in the same house. When the beds were sampled at the end of the experiment it was found that the largest numbers of larvae were

TABLE I

EXPERIMENT D.3. YIELD PER BED AFTER TEN WEEKS' CROPPING

Spawn	Spawning to pinheads	No.	Wt.	Mean yield
	<i>days</i>		<i>g.</i>	<i>oz./sq. ft.</i>
D/1/2	58	108	2735	10.5
D/2	53	134	3556	14.0
T/1	59	72	1150	4.5
S/1	57	87	1251	5.0
H/1	77	19	272	1.0
L/1 tissue	70	94	1975	7.5
Control	53	193	4363	17.0

in the beds with the least mushroom mycelium. This lack of mycelium did not appear to be primarily due to larval attack, but to the slow rate of growth of the spawns concerned. The compost had retained its original dark colour, indicating that it had never been colonised by the mushroom mycelium. Growth in sterile compost is also known to be slow. The control beds were filled with mycelium, but the larval population was lower than in those beds with slow growing mycelium. The conditions necessary for the onset of fly attack appear from this to be more complex than at first believed.

There is evidence that the type of disorder under investigation is greatly influenced, if not caused, by environmental conditions. Mushroom trays and sections of beds which had shown the disorder were transferred to a glasshouse and kept under conditions of lower atmospheric humidity and temperature than are usually found in mushroom houses. In all cases where the trays and beds continued to crop, the mushrooms produced were either normal and healthy, or became so in the flush following the transference of the material. Sections of bed from two widely separated farms were kept in the mushroom house, and the sporophores produced in this case were misshapen and died before reaching maturity. Water extracts of mushrooms, casing and compost from these beds were sprayed on to beds which were cropping normally. There was no visible effect on the quality of mushrooms produced subsequently, nor on the rate of cropping.

Laboratory experiments

The casing material from affected crops was tested for the presence of *Fusarium* spp. in the manner described by Wood (6). All the results were negative.

Further studies were made of the growth on agar media of mushroom cultures isolated from abnormal crops. New cultures obtained during the year and included in the experiments were:

E/1 Obtained from a farm in Rutland.

T/2 Obtained from the same farm as T/1 (W. Sussex)

T/2 Tissue. Tissue culture of an abnormal sporophore from the same crop as T/1 tissue

S/2 Obtained from the same farm as S/1 (W. Sussex)

Petri dishes have not been entirely satisfactory for these growth measurements. There is considerable wastage through contamination, and serious drying out of the medium occurs after about three weeks' incubation. The use of Petri dishes was therefore discontinued, and Pyrex glass tubes of the type devised by Ryan *et al.* for their growth-rate studies of *Neurospora* were used, instead. With this technique mushroom cultures can be kept in a state of active growth for many weeks. The results of the first experiment with these tubes are given in Table II.

TABLE II

MEAN COLONY LENGTH IN MM. NINE WEEKS AFTER INOCULATION

Control	D/1	D/2	D/2/2 tissue	D/3	E/1	G/1	G/2	M/1 tissue	S/1	S/2	T/1/2	T/2	T/2 tissue
110	85	72	106	123	98	115	79	98	70	99	109	74	92

There were very noticeable differences in the appearance of several cultures. D/1 produced very little aerial mycelium and there was no production of rhizomorphs. The mycelium was a creamy buff colour, which contrasted with the pure white of what is regarded as normal mycelium. The older mycelium appeared to undergo some degeneration. In the more vigorous cultures, rhizomorphs were well developed and tufts of fluffy aerial mycelium were produced at regular intervals along their length. These correspond to the annular type of growth found in cultures growing on plates.

A start has been made on the microscopic examination of abnormal mushroom tissue. Portions of stipe tissue showing the "watery streak" condition were fixed in a weak chrom-acetic solution, embedded in paraffin wax and sectioned. The sections, 3, 5 and 8 μ thick, were stained in Heidenhain's haematoxylin. In the waterlogged streaks the tissues were seen to have become disorganised, the cell walls having broken down. In these areas the damaged hyphae and inter-hyphal spaces were colonised by bacteria.

As previously mentioned, the mushrooms produced in experiment D3 were attacked by a parasitic fungus, the symptoms at first appearing very similar to those caused by a mild attack of *Verticillium*. Dark brown spots and blotches appeared on the pilei, and a fine grey-white mycelium could be seen growing on these spots. The fungus was not a *Verticillium* sp., however, but appeared to be identical to the *Acremonium* sp. described by Bulloch (1); this was confirmed by Bulloch himself. Diseased material was submitted to the Plant Pathology Laboratory where the fungus was identified as *Cephalosporium lamellaecola* Smith. At a later stage in the disease a fine cobweb-like mycelium could be seen growing over the gills, the lamellae of which appeared to be stuck together in places. It appears from the evidence now available that Bulloch's *Acremonium* disease is identical with Smith's gill mildew, *Cephalosporium lamellaecola*.

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VI. ENTOMOLOGY

1. GREENHOUSE WHITE FLY (*TRIALEURODES VAPORARIORUM* WESTWOOD)

by

N. W. HUSSEY & BARBARA GURNEY

Synonymy of *T.sonchi* Kotinsky

It was observed that pupae on *Sonchus* weeds under glass differed markedly in the development of the dorsal wax processes from those on tomato or tobacco. The form on *Sonchus* was obviously that known as *T.sonchi* Kot. (Trehan, 1940) on account of the very long dorsal wax threads. By cross-inoculations of pupae reared on *Sonchus* to tomato and vice-versa, it was demonstrated that the development of these processes depended on the host; hence *T.sonchi* must be sunk in *T.vaporariorum* (Hussey and Gurney, 1957).

Effect of temperature on rate of development

Although Weber (1931) has published a monograph on *Trialeurodes vaporariorum* and its natural enemies, the basic information necessary for valid predictions of the efficiency of the parasite *Encarsia formosa* Gahan is still lacking. There is no information on the fecundity and development of *Trialeurodes* under different environmental conditions, and studies were initiated to fill this gap in our knowledge. The figures obtained on egg incubation are plotted in Figure 1, together with data derived from Weber's paper. The work on nymphal development is incomplete, but the information obtained to date is recorded in Table I. These studies were carried out on detached tomato leaves rooted with the aid of hormone solutions in damp vermiculite.

TABLE I
MEAN DEVELOPMENT PERIODS OF THE INSTARS OF *T. vaporariorum*
AT CONSTANT TEMPERATURE (IN DAYS)

Temp. (°F.)	Instar I	II	III	Pupa	Total
80	3.0	2.2	2.5	5.5	13.2
75	2.4	2.2	3.2	6.0	13.8
70	3.3	3.3	2.7	6.0	15.3

The investigation of fecundity revealed that at any given temperature the rate of egg production by each female per day was relatively constant, but the length of adult life varied over wide limits and it will be necessary to extend the observations to obtain more useful data. In Table II the standard deviations show the extent of the variation observed.

TABLE II
FECUNDITY AND LONGEVITY OF FEMALE *Trialeurodes* AT DIFFERENT
TEMPERATURES, WITH STANDARD DEVIATIONS

Temp. (°F.)	No. females	Longevity (days)	Eggs/♀/day
80	16	22.5 ± 10.4	10.8 ± 3.7
75	7	36.3 ± 21.0	5.8 ± 3.4
60	12	31.3 ± 19.5	4.2 ± 1.1

Effect of tomato variety on fecundity

Some preliminary results were obtained on the suitability of three distinct tomato varieties for oviposition by White-fly. Tests were made by caging 40 pupae on three plants of each of three varieties, "Potential", "St. Pierre" and "Ailsa Craig". After 28 days, 10 sample leaves were removed from each plant, and the total number of eggs deposited on them was determined by counting all the stages present. An estimate of the proportion of the total leaf area sampled was obtained by comparing the amount of water displaced in a measuring cylinder by the sampled and unsampled leaves. Although the density of eggs per leaf was apparently greatest on "Potential", the plants of this variety were smaller than those of the other two varieties, and estimates of the total numbers of eggs per plant did not suggest significant differences between varieties (Table III).

TABLE III
TEST FOR HOST PREFERENCE BY FECUNDITY OF *Trialeurodes*

Tomato variety	Mean no. of eggs on 10 sample leaves	Mean estimate of total eggs per plant	Eggs/♀
"Potential"	599	2064	51.6
"St. Pierre"	520	2326	58.2
"Ailsa Crag"	473	2057	51.4

A parasitic fungus *Cephalosporium aphidicola* Petch

In the course of rearing White-flies for biological studies a number of adults were observed to be attacked by *Cephalosporium aphidicola* Petch, the determination of which was kindly confirmed by the Commonwealth Mycological Institute. The main experimental conclusions of the studies briefly mentioned here will be found in a paper by Hussey (1958).

Infected adults were observed to produce large ventral wax bundles a few hours before death. Some 36 hours after death a fine mycelial web bearing capitate conidiophores covered the dead insect and spread over the adjacent leaf surface. Artificial infection by spraying spore suspensions showed that only the eggs and active first instar nymphs were immune to hyphal penetration. The optimum environmental conditions required by the fungus spores for germination were also studied to ascertain the possibilities of economic control. However, the spores needed about 24 hours at saturation to secure a high percentage germination, and as tomato foliage could not be subjected to such conditions without other cultural or phytopathological difficulties further development of the control method was abandoned.

Population sampling

To provide information on the problems involved in assessing White-fly populations, eight tomato plants were placed in a greenhouse sub-compartment with heavily infested tobacco plants on April 17th. The resulting *Trialeurodes* population was first assessed on May 1st when the plants were about 16 inches high. Sampling was then carried out by counting the total numbers of eggs, scales and pupae on opposite pairs of leaflets at two fixed height zones, (i) at half plant height, and (ii) at two inches below the growing point. By May 22nd these counts had risen to a mean level of about 430 scales per leaflet, with a maximum of 1683. Thereafter the method of assessment was changed by making observations on two $\frac{3}{8}$ in. discs, cut by a cork-borer, from the opposite leaflets. When sampling ceased on June 26th the average count was 1106 scales per disc on the upper leaves. At this high population level very severe damage was caused by the dark brown mould, *Cladosporium sphaerospermum*, growing on the accumulated honey-dew, and the plants died by mid-July.

These exploratory samplings suggested three variables which must be taken into account in future research requiring the assessment of White-fly populations: (i) there is a very definite tendency for the adult females to choose the sub-apical leaves for oviposition (Table IV), although the differences are much less marked if leaf growth is taken into account; (ii) comparing the populations on discs from leaves of which the orientation of the upper surface was recorded, there was apparently a greater population on the west side within any one height zone. The populations recorded on leaflets in the four compass quadrants were: N.E. 15.2/disc, S.E. 6.4/disc, S.W. 29.3/disc, and N.W. 31.2/disc; (iii) although the females prefer to oviposit on the upper leaves, further eggs were laid on the developing leaves, as the comparisons in Table V, for the same height zone at different dates, indicate.

TABLE IV

WHITE-FLY POPULATION DENSITY ON DISCS FROM DIFFERENT HEIGHT ZONES ON A TOMATO PLANT 41 IN. HIGH AND BEARING FOUR TRUSSES ON 21.5.57

Height zone	Eggs and scales per disc
Below 1st truss	0.9
Between 1st and 2nd trusses	9.6
Between 2nd and 3rd trusses	17.6
Between 3rd and 4th trusses	64.4
Above 4th truss	37.0

TABLE V

WHITE-FLY POPULATIONS IN THREE HEIGHT ZONES AT DIFFERENT STAGES OF PLANT GROWTH

Height zone	Population when height zone was approximately:—	
	Apical	Half plant height
14–18in.	41/Leaf	138/Leaf
18–25in.	121/Leaf	427/Leaf
36–42in.	130/Disc	284/Disc

It is therefore evident that disc sampling must be adopted, although it will be necessary to compute the areas of the leaves from which the discs are cut to permit comparison between different height zones. The discs must be cut from leaves at different heights and with different orientations on each plant.

The White-fly parasite *Encarsia formosa* Gahan

Preliminary observations were made to confirm and extend the information recorded by Speyer (1927). Two points of interest emerged which it is hoped to follow up.

At the point of entry of the ovipositor into the scale of *Trialeurodes* an exudation occurs which within a few hours turns dark brown to black. Many scales carried more than one of these punctures, although only one larva was found on dissection. Burnett (1943) has recorded as many as nine parasite eggs in a single scale but makes no mention of the oviposition scar. The ovipositing females seem to probe the host tissues in a manner which suggests they are searching for previously laid eggs. This may imply that they are incapable of detecting previous parasitism by external scent. It is possible that careful observation will show that the location of the oviposition punctures relative to each other will determine the extent of super-parasitism. A few females

were observed to place their mouthparts on these punctured holes, so it seems possible that *Encarsia* needs to feed on protein material to promote fecundity. First instar nymphs do not normally appear to attract the parasite, but in the few cases when this instar was attacked the nymph was killed by the act of oviposition.

In 3 in. $\times$ 1 in. tubes adult parasites did not seem able to search for scales as successfully on bean leaves as they did on tomato. As it is widely held that *Encarsia* holds most promise as a control for White-fly for the general grower, its efficiency on different host plants should obviously be investigated.

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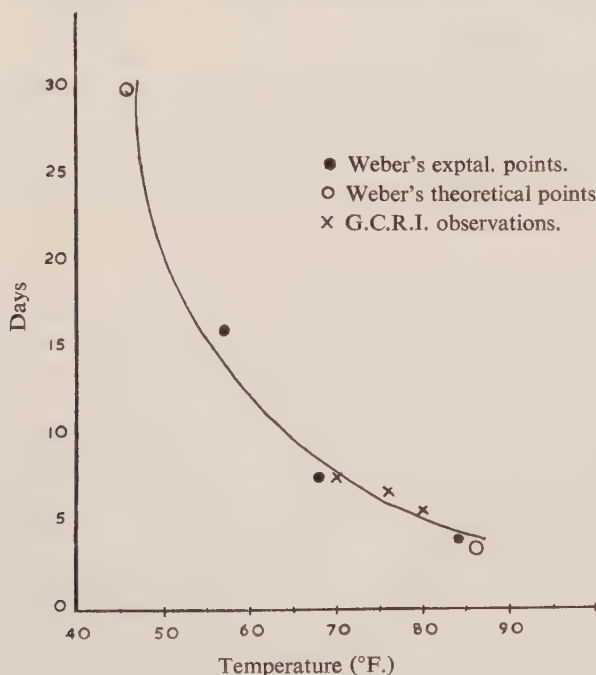


FIGURE 1. Incubation period of eggs of *Trialeurodes vaporariorum*.

2. MUSHROOM INSECTS

by

N. W. HUSSEY & I. J. WYATT

Fauna of light racing stable manure

The results obtained during the first six months of the faunal study were recorded in the 1956 Annual Report. Sampling was concluded in May, 1957, and the species list for the last six months is given in Table I. A further eight species were bred out making a total of 72 species identified altogether, in addition to catches in the following Dipterous families which were not determined:— Sepsidae, Empidae, Psychodidae, Chironomidae, Cecidomyiini, Dolichopididae and Culicidae. A paper on the ecology of the Sphaeroceridae (Hussey, 1957) has been prepared for publication to show the contrast with the fauna of that family associated with cowpats reported by Laurence (1955). Forty of the recorded species were Coleoptera, an order which has not so far been recorded as containing a mushroom pest, and a further sixteen were Sphaeroceridae, a family whose status is in dispute. Of the remainder of the fauna only the Sciaridae are of importance. The same five species previously reported were reared. From the data over the twelve month period it appears that *S.fenestralis* and *S.umbratica* are absent from the manure between November and March, while *S.modesta* and a species recorded as "F" were only reared from samples collected in midsummer. Only *S.auripila* could, on the present observations, be said to occur in the habitat throughout the year. (In a later paragraph taxonomic studies on these Sciarid species are reported, but for the sake of continuity the names used in the 1956 Report are retained in this Section).

Comparing the age of the manure from which the various species have been bred (Table II), it is evident that *S.umbratica* prefers manure about three weeks old, whilst *S.fenestralis* and *S.modesta* choose almost fresh material.

The developmental periods calculated from the breeding records agree quite well with the only published information. Austin and Jary (1933) gave figures for *S.fenestralis* between 29 and 44 days, while Parr, Crocker and Speyer (1954) showed that *S.modesta* could develop in 36 to 53 days. Both these published records are based on laboratory rearings, whereas the present data are based on samples kept partially under field conditions.

Cecid investigations

The work on the paedogenetic Cecids infesting mushroom beds has been quite fully reported by Hussey & Wyatt (1958), but mention will be made here of the results of investigations on the specific identity of the flies involved. Barnes (1946) listed six species infesting mushroom beds, but our studies show only four need be considered in Great Britain. Of these *Lestremia cinerea* Macquart is only an occasional pest, and *Mycophila barnesi* Edwards and *M.speyeri* Barnes, although often present, do not appear to be so important economically as *Heteropeza pygmaea* Winn. Characters for distinguishing all these species have been mentioned in the above paper.

A method of rearing the larvae on sterile cultures of mushroom mycelium has been developed, and some preliminary observations made on the effects of starvation on larval populations. In general, it seems that a complicated balance is involved, for in slowly starved cultures the majority of the larvae become sexual, but in crowded cultures, where starvation affects individual larvae suddenly, they usually become senescent. These senescent mother larvae are yellow-brown in colour and develop a tough, chitinous skin from which the daughter larvae have difficulty in emerging. Whether this is a definite adaptation to resist unsuitable environmental conditions remains to be established.

TABLE I
FAUNA OF RACING STABLE MANURE EXPOSED FOR MONTHLY PERIODS
FROM INDICATED DATES

DIPTERA	11/12/56	8/1/57	5/2/57	6/3/57	9/4/57	14/5/57
<i>Sphaeroceridae</i>						
Leptocera clunipes (Mg.)	37	183	352	705	70	148
L. coprina Duda					2	58
Limosina silvatica (Mg.)	5	3	19	13		
Sphaerocera curvipes Latr.				17	2	91
S. pusilla (Fall.)					4	112
S. monilis Hal.				3	1	9
Trichiaspis equina (Fall.)	420	718	165	163	468	33
T. similis (Collin)						8
<i>Muscidae</i>						
Dendrophaonia querceti (Bouché)						8
Fannia canicularis (L.)						4
<i>Tipulidae</i>						
Rhipidia maculata (Mg.)						81
<i>Cordiluridae</i>						
Scopeuma stercorarium (L.)	4	11	10	2	1	14
<i>Sciaridae</i>						
Sciara auripila Winn		5		12		
S. fenestralis Zett					49	
S. modesta Staeger	357		440		8	35
S. umbratica Zett				21	1	5
S. sp. "F"	17	99	30			
<i>Psychodidae</i>	112	128	589	813	86	753
<i>Chironomidae</i>	21	12	7	23	14	91
<i>Culicidae</i>	1					
<i>Dolichopodidae</i>	4		3			
<i>Cecidomyiidae</i>						
Cecidomyiini					51	
Lestremiinae					5	
Monardia nigricans				2		
COLEOPTERA						
Anotylus tetracarinatus (Block)						6
A. inustus Gravenhorst						1
Atomaria nigriventris Steph.					3	
Philonthus fimetarius Grav.						1
P. carbonarius Gyll				1	1	
Aphodius fimetarius (L.)						1
Acrotrichis grandicollis (Mann.)					2	
Megasternum obscurum (Marsh.)					7	6
Cercyon haemorrhoidalis F.					1	5
C. melanocephalus (L.)					13	
Oxyomus sylvestris Scop.		1			1	
Tachinus subterraneus (L.)		1				
Tachyporus hypnorum (F.)			1			
Onthophilus striatus Forst.					12	
Anthobium atrocephalum Gyll.					2	3

TABLE II

MEAN AGE OF MANURE AT OVIPOSITION AND MEAN DEVELOPMENTAL
PERIOD OF SCIARIDAE IN RACING STABLE MANURE

Species	Mean age of manure at oviposition (days)	Mean developmental period (days)
<i>S. umbratica</i>	23.3	41.1
<i>S. fenestralis</i>	2.0	61.5
<i>S. auripila</i>	10.8	44.0
<i>S. modesta</i>	4.0	56.0
spp. "F"	12.6	35.2

Some experiments were made to determine the maximum lethal temperature of *Heteropeza* and *M.barnesi* to establish whether normal peak heating treatments would kill larvae which might be present in composting materials. These tests showed that *Heteropeza* succumbs at 113°F. and *M.barnesi* at 99°F.

Preliminary studies on the rates of larval development at constant temperatures showed that over the range 70°F. – 85°F. the duration of the paedogenetic generation was reduced from a mean of 9.5 to 8.1 days. The mean number of offspring per mother also fell from 10.2 to 7.0, but this is possibly due to inhibition of mycelial growth at high temperatures.

Work has also been initiated on the natural habitats of these Cecid species, and the following sites have been established. *M.speyeri* is only known from mushroom compost, but *M.barnesi* has been found in garden manure, rotting potatoes and peat, as well as in compost. *Heteropeza* larvae have been recorded in soil with a high humic content, in dry greenhouse soil in which a single mushroom appeared, below birch bark, in the body-work of an old motor car and in compost.

These investigations have involved the study of similar species in the Lestremiinae and Heteropezinae, and techniques for permanent preparations have been tried out for future taxonomic studies in these families.

The observation that paedogenetic larvae can occasionally produce grand-daughters within themselves suggested that further information on the mechanism of larval nutrition was desirable. Studies on the internal anatomy by means of serial sections have therefore been started.

Eelworm parasitic on *Megaselia halterata*

Early in September examination of adult Phorids from a heavy attack at a local farm showed that many were infected by a parasitic eelworm. Specimens were submitted to Dr. H. Welch of the Belleville Parasite Laboratory in Canada who has identified them as a new species of the genus *Bradynema* (family Allantonematidae). A series of samples from the affected farm showed that between 70 and 80% of the adult *Megaselia* were parasitized.

The life-cycle of this parasitic nematode is probably as follows. A fertilized female eelworm penetrates the cuticle of the Phorid larva by means of a spiral entrance hole and enters the haemocoel; when the Phorid reaches the pupal stage the female eelworm has grown enormously to become sausage-shaped; eggs and larvae are liberated by this female into the blood of the insect soon after pupal eclosion; when these larvae are in the second or third instar they emerge from the genital or intestinal openings and mature to free-living sexual nematodes. The activity of the adult flies does not seem to be impaired by the large eelworm populations within their bodies for

samples of copulating pairs showed that 83% of both sexes were parasitized. The female reproductive system is affected, however, for although the genital organs are present they are greatly reduced in size and the infested females usually only have 1-5 eggs compared with the normal 50. There is some evidence that even the few eggs produced are infertile.

As peak-heating produces what amounts to a biological vacuum in the compost it appears possible that if a high proportion of the larvae of the first Phorid generation could be infected artificially, the reproductive potential of the infestation could be reduced below that causing economic loss, especially in the case of tray growers.

Taxonomic investigations on the Sciarids infesting mushrooms

The specific determination of the Sciaridae has been based in the main on the distinctive genitalia of the male, and the references to female characters in the available literature are largely unsatisfactory. The illustrations of the species known to infest mushroom beds are scattered in the works of Austin and Pitcher (1937), Seguy (1940) and Lengersdorf (1934).

Up to 1957 the following species have been recorded from mushrooms:— *Neosciara auripila* Winn., *N. brunnipes* Meig. (= *umbratica* Zett.), *N. fenestralis* Zett. (= *agraria* Felt), *N. hilaris* Winn., *N. modesta* Staeg., *N. nitidicollis* Meig., *N. parapusilla* Winn., *N. praecox* Meig., *N. pusilla* Meig., and *Sciara varians* Johannsen.

The publication of Frey (1942) makes it necessary to reassign several of these species to new genera, and the following terminology should be applied to the seven species which have been collected at the Institute:— *Lycoriella auripila*, *L. fenestralis*, *L. sp. "J"*, *Neosciara brunnipes*, *Hemineurina modesta*, *L. sp. "F"* and *Prosciara sp. "V"*,

The correct specific identity of those species denoted by letters is still under investigation, but in view of the difficulty of determining species in this family the female wing venation and male genitalia of all seven species are illustrated (Figures 1-15). The following provisional key to the females is appended. Males are only rarely trapped, and interpretation of the light and suction trap catches depends on identification of the females.

Provisional key to the female Sciaridae associated with mushroom compost

- 1(2) X and Y bearing macrotrichia (Fig. 5) *Prosciara sp. "V"*
- 2(1) X and Y not bearing macrotrichia
- 3(4) Antennal segments as broad as long (Fig. 8a) *Hemineurina modesta*
- 4(3) Antennal segments longer than broad
- 5(6) Antennal segments stalked (Fig. 8b); only a few macrotrichia on M (Fig. 2) *Lycoriella sp. "J"*
- 6(5) Antennal segments not stalked
- 7(10) Portion R1/2, distad to junction with R/S, long; apex of R1/2 almost reaches fork of M2 (Fig. 1)
- 8(9) Y with some macrotrichia apically (Fig. 4) *Neosciara brunnipes*
- 9(8) Y with no macrotrichia (Fig. 1) *Lycoriella fenestralis*
- 10(7) Portion 1/2, distad to junction with R/S, short (Fig. 7)
- 11(12) Extension C beyond M long (c/w more than 0.7) (Figs. 2 & 7) .. *Lycoriella auripila*
- 12(11) Extension C beyond M shorter (c/w less than 0.6) (Fig. 6) .. *Lycoriella sp. "F"*

FIG. 1

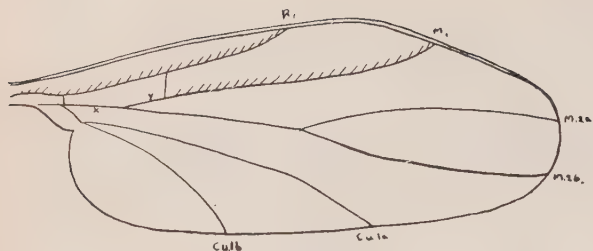


FIG. 5

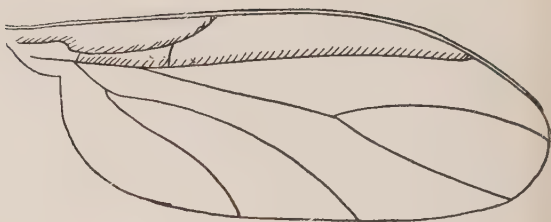


FIG. 2

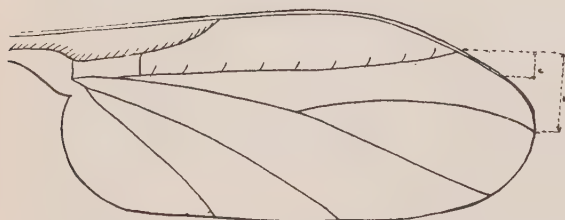


FIG. 6

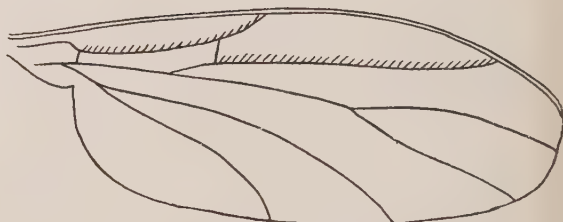


FIG. 3



FIG. 7



FIG. 4

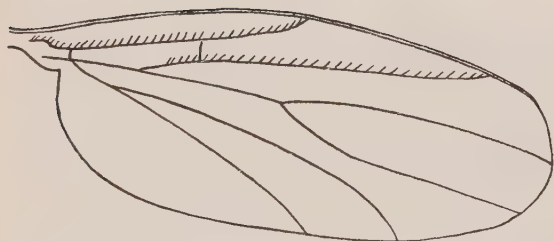
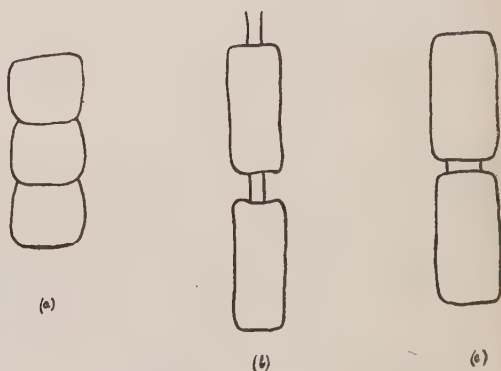


FIG. 8



FIGURES 1-7. Mushroom sciarids; female wing venation.

FIG. 1. *Lycoriella fenestralis*.

FIG. 2. *L. "J"*.

FIG. 3. *Hemineurina modesta*.

FIG. 4. *Neosciara brunnipes*.

FIG. 5. *Prosciara* sp. "V".

FIG. 6. *H.sp. "F"*.

FIG. 7. *L. auripila*.

FIG. 8. Mushroom sciarids; female antennal segments.

FIGURE 8. Mushroom sciarids; female antennal segments. (a) *H. modesta*. (b) *L.sp. "J"*. (c) *L. fenestralis* sp.

FIG. 9



FIG. 10

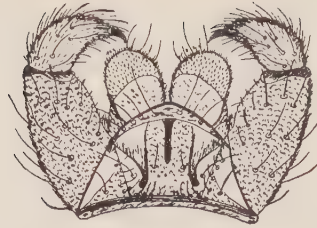


FIG. 15



FIG. 12



FIG. 11



FIG. 14



FIG. 13



FIGURES 9-15. Mushroom sciarids; male genitalia. FIG. 9. *L. auripila*.
FIG. 10. *L. sp. "J"*. FIG. 11. *Prociara sp. "V"*.
FIG. 12. *H. modesta*. FIG. 13. *L. fenestralis*.
FIG. 14. *H. sp. "F"*. FIG. 15. *Neosciara brunripes*.
(Scales indicate 0.1 mm.)

Aerial fauna in mushroom house

The light trap was operated during the whole of the growing season between April and August. The catches will not be presented in detail until several are available for constructive analysis. It is, however, worthy of record that adult *Heteropeza* were trapped in small numbers (up to five a week) in each of the first four weeks following filling. It was not possible to sample beds for larvae during cropping, but after 20 weeks the Cecid larval populations were as high as 185 per 20 gram sample, although only two more adults were trapped in the previous 16 weeks.

The following species of Lestremiinae were also trapped:— *Monardia nigricans* Edwards, *Johannisia palustris* Kieffer and *Mycophila speyeri*.

Traps placed in the roof-vents were also examined at the same weekly intervals as the light trap, but the frequency of occurrence of the potential mushroom pests did not differ from the trends shown by the light-trap itself.

A suction-trap has been designed and constructed to compare its efficiency with that of the light-trap, especially in the case of less strongly positively phototropic species such as male Sciarids.

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3. RED SPIDER MITE (*TETRANYCHUS URTICAE* KOCH)¹

by

N. W. HUSSEY & W. J. PARR

Colour complex

The studies of the colour complex in this species were completed during the year, and the conclusion was reached that there are two forms which are sub-generically distinct (Hussey and Parr, 1958). The reddish-brown form found in Great Britain may not be synonymous with *T.cinnabarinus* Boisduval, and judging by the results of the breeding experiments by Boudreaux (1956) and Keh (1952) the American green form *T.telarius* L. (= *bimaculatus* Harvey) may be distinct from *T.urticae*. The British reddish-brown and green forms will hybridize, but the females produced are usually sterile, though occasionally they can produce male offspring. The latter give rise to various hybrid forms when mated with reddish or green females. The implication is, therefore, that acaricide testing must be conducted only on pure clones derived from single females mated with their own sons. Taylor and Smith (1956) have demonstrated the existence of resistant strains in the U.S.A., and Dosse (1952) has given evidence of considerable differences in the resistance of red and green forms to systox.

Effects of humidity on physiology

It has been asserted that high humidity is deleterious to mite populations, and to provide information on this possibility mites were kept on leaf discs floating on nutrient solution in open and closed Petri dishes. In closed dishes the humidity was of course at saturation, and the discs were covered with condensation droplets. Using a modified Piche evaporimeter (Hussey, 1956) the evaporation rate within 2 mm. of the disc surface in the open dishes was shown to be 0.5 mm./min., which is still very low compared with rates of 4.8 mm./min. observed below tomato leaves in a glasshouse on a sunny day. When mites were exposed for four days to various periods of saturation alternated with the conditions of lower humidity referred to above, the fecundity was shown to decrease with increase of exposure to saturation (Table I).

TABLE I
FECUNDITY OF *T.urticae* (GREEN FORM) FOLLOWING EXPOSURE TO
DIFFERENT PERIODS OF SATURATION OVER FOUR DAYS

Daily period of saturation (hours)	Mean no. eggs/female/day
24	9.3
20	11.7
16	12.0
8	12.8
0	13.4

In Table II the reactions of both reddish-brown and green forms are compared at different temperatures. From the data it is evident that the fecundity of both forms is adversely affected by high humidity and, also, that for any combination of temperature and humidity the green form

¹ In accordance with recommendations made at the Symposium of Acarology held at Wageningen in 1956, and pending the completion of further systematic studies, the specific name *urticae* is here adopted in preference to *telarius* L. for the red spider mite of Europe.

tends to reproduce more rapidly than the red, though this requires further investigation. Unpublished data provided by Boudreaux show a similar reduction in fecundity at high humidities in *T.telarius* and *T.cinnabarinus*. Boudreaux's figures and those of Lehr and Smith (1957) show that *cinnabarinus* has a higher reproductive potential than *telarius*.

TABLE II
FECUNDITY OF FEMALE *T.urticae* (REDDISH-BROWN AND GREEN
FORMS) AT DIFFERENT TEMPERATURES AND HUMIDITIES, EXPRESSED
AS NUMBER OF EGGS PRODUCED PER FEMALE PER DAY

Temp. (°F.)	Open petri dishes		Closed petri dishes	
	Green	Reddish-brown	Green	Reddish-brown
85	20.6	12.6	19.0	10.0
80	11.9	10.1	8.5	6.0
75	10.1	—	5.6	4.4
70	6.1	2.4	5.3	0.6
65	4.5	—	1.1	—

In practice, the trends suggested in Table II will be affected by (a) differential effects of temperature on the rate of growth of the reddish-brown and green forms, and (b) differential mortality of the developmental stages at low saturation deficiencies.

For the reddish-brown form the relation between rate of development and temperature has already been studied by Hussey, Parr and Crocker (1957), and similar experiments on the green form have given identical results.

Table III shows that the development of the two colour forms is little affected by long periods of saturation, although the green seemed slightly more resistant to these conditions.

TABLE III
EFFECT OF VARIOUS PERIODS IN A SATURATED ATMOSPHERE ON THE
COLOUR FORMS OF *Tetranychus urticae* KOCH

Colour form	Hours per day in saturated atmosphere	No. eggs in sample	No. hatched	Viability (%)	No. young in sample	Matured (%)	Sex	
							♀	♂
Reddish-brown	0	93	91	98	20	100	16	4
	8	90	83	92	30	83	16	9
	16	97	92	95	30	87	20	6
	20	78	74	95	40	90	20	16
	24	96	86	90	40	82	24	9
Green	0	63	62	98	20	100	13	7
	8	69	68	98	30	100	25	5
	16	78	69	88	30	100	22	8
	20	80	68	85	40	97	34	5
	24	81	73	90	40	90	27	9

Study of initial infestation on a cucumber crop

An attempt was made early in the year to gain information on the initial infestation of the mite upon the cucumber crop at this Institute. A considerable infestation was present on the plants at the end of the previous crop, and the usual winter programme of cleaning up the houses had been carried out. The border soil had not been steamed, however.

Observations were carried out in two pairs of houses separated by a brick wall. The plants consisted of many varieties germinated on 4th January, and set out in randomised blocks in the houses on 5th February. They were examined at 4-5 day intervals during propagation, and at weekly intervals after planting out.

The first feeding marks of the mite were observed on 5th March on a single plant in each of two houses and situated about half-way down each house. The marks were confined to one or two leaves low down on the plants, which were at this time 7-8 ft. in height. In each case one female and young stages were present. A further examination of these plants three days later revealed the presence on one of some 12 green females with many young, mostly in the deutonymph stage, and only a few eggs, and on the other, some 20 green females with many deutonymphs and a large number of eggs. It was concluded from this that the mites of the first generation had completed or were about to complete their development, and that some of the newly matured females had in fact commenced to oviposit. Under the conditions of temperature prevailing it is computed that the initial invasion of these plants by single females must have occurred about 20th February.

Between 11th-15th March a second plant in one of these houses, and two in a third house hitherto uninfested, showed feeding marks on the lower leaves. Again the plants were situated near the middle of the house, though not in close proximity to the original site of infestation.

By 25th March, when it was considered advisable to apply acaricidal treatment, a considerable build-up of infestation, both on the original and adjacent leaves of these five plants had taken place, and a limited amount of spread to neighbouring plants was evident. Examination of a number of leaves showed the presence of a large number of green females, together with many eggs and young stages. No reddish-brown females were observed.

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VII. CROP PROTECTION

1. INVESTIGATIONS ON THE CONTROL OF CHRYSANTHEMUM MILDEW

by

W. H. READ

Little work on the control of chrysanthemum mildew (*Oidium chrysanthemi*) has been undertaken during recent years and fungicides recommended against this disease cannot be regarded as very satisfactory. The sprays now used give a shorter period of protection than copper oxychloride-petroleum sprays, which have proved much too phytotoxic for use on many of the present-day commercial varieties of chrysanthemum. In the absence of damage the appearance of the foliage of chrysanthemums is improved by the application of sprays containing petroleum. The slight deposits from repeated applications of salicylanilide dispersions may adversely affect the foliage, however.

The results of a preliminary test made in 1956 indicated that "Karathane", a proprietary product containing about 20 per cent of technical 2:4-dinitro-6-(2-octyl) phenyl crotonate formulated as a dispersible powder, when applied at 0.006 per cent active ingredient was superior to salicylanilide at 0.08 per cent.

From past experience it was known that chrysanthemums may be tolerant to certain mixtures of pesticides with petroleum oil emulsions which are highly toxic to most other plants, in particular to cucumbers. A trial was therefore made in which salicylanilide, thiram and "Karathane" were applied normally and also in combination with petroleum.

Experimental

In these experiments chrysanthemums (varieties "Rolinda", "Loveliness", "Balcombe" and "White Progress") were placed singly in 10-inch pots and grown out-of-doors until the third week in September, when they were placed in a glasshouse. The cultural practices of fertilising with top dressings, "stopping" and "dis-budding" were carried out in accordance with normal practice when plants are grown in pots and taken under glass in the autumn. Aphids and leaf miners were controlled by spraying with a miscible *gamma* BHC preparation.

Delays in completing the construction of the research glasshouses in which the plants were to have been housed made it necessary to use makeshift alternative accommodation which had to remain unheated during the latter part of the trial. The conditions were therefore unsatisfactory in some respects for a trial of this nature in which the recording of phytotoxic effects is required. On the other hand, the conditions were evidently suitable for mildew development. Plants heavily infected with mildew were already present in the glasshouse when the chrysanthemums for these trials were housed.

Four applications of the sprays were given, commencing on October 9th, when the first signs of mildew were detected on several plants, a second application being made after an interval of three weeks, and the third and fourth after further intervals of two weeks.

Sprays applied and concentration of active material

- (a) Salicylanilide—0.08 per cent.
- (b) Salicylanilide—petroleum mixture. 0.08 per cent salicylanilide, 0.3 per cent petroleum. Prepared by adding a suspension of salicylanilide to a diluted commercial petroleum emulsion. The petroleum emulsion was approved as a Summer Wash for Glasshouse Use, under the Crop Protection Products Approval Scheme.
- (c) Thiram—0.08 per cent. Prepared from a commercial dispersible powder.

- (d) Thiram—petroleum. 0.08 per cent thiram, 0.3 per cent petroleum (see (b)).
- (e) 2:4-dinitro-6(*sec.* octyl) phenyl crotonate—0.006 per cent of the commercial crotonate. Prepared from the proprietary dispersible powder formulation “Karathane” containing about 20% of the commercial crotonate.
- (f) 2:4-dinitro-6(2-octyl) phenyl crotonate—petroleum. 0.006 per cent crotonate, 0.3 per cent petroleum (see (e) and (b)).
- (g) Petroleum emulsion—0.3 per cent petroleum.
- (h) No fungicide.

Results

The severity of mildew attack on the foliage was estimated visually on the stems arising from the final “stopping” immediately before and one week after each spraying. Numbers from “0”, where only very few, inconspicuous, isolated spots of the fungus were detected on the leaves or the stems, to “5”, where more than 30 per cent of the leaf area was infected, were allotted to each plant, and the mean for each treatment is given in Table I.

TABLE I
RESULTS OF TREATMENTS FOR CONTROL OF CHRYSANTHEMUM MILDEW

Treatment	Severity of mildew infection					
	16 Oct.	30 Oct.	6 Nov.	13 Nov.	27 Nov.	10 Dec.
(a)	0	2	1	2	2	2
(b)	0	1	0	0	0	1
(c)	1	4	2	3	3	4
(d)	0	2	1	2	1	1
(e)	0	2	2	1	1	1
(f)	0	2	1	0	1	0
(g)	1	3	2	3	2	3
(h)	1	3	3	4	5	5

The estimation of the amount of a fungus such as *Oidium chrysanthemi* on the foliage of chrysanthemums is not easy, as in the early non-sporing stages of the infection the extent of the mycelium can only be determined with difficulty. The order of merit of the treatments, as judged by independent persons solely by observation, conformed with that derived from the numerical assessment, however.

The results show that under the conditions of these tests the best control of chysanthemum mildew was obtained with salicylanilide or “Karathane” in combination with a petroleum emulsion. Observations suggest that the superior control may be due to the longer period of protection afforded by the addition of petroleum to the fungicides. It will be seen that the petroleum emulsion alone gave a substantial degree of control.

Although mixtures of salicylanilide, thiram or 2:4-dinitro-6-(2-octyl)phenyl crotonate (“Karathane”) with petroleum are injurious to certain other plants, in particular to cucumbers, no damage to the chrysanthemums used in these experiments was observed.

It is important to note, however, that these tests have been made on four varieties of chrysanthemums only. There are very pronounced varietal differences in the response of chrysanthemums to pesticides, and climatic and cultural conditions also have an effect on susceptibility to damage. Growers should therefore not use salicylanilide or “Karathane” in combination with petroleum emulsions except experimentally. The most satisfactory concentrations of fungicide and petroleum can only be determined by a large number of trials on a wide range of chrysanthemum varieties.

2. THE DETERMINATION OF RESIDUES OF DIAZINON ON CUCUMBERS

by

W. H. READ & J. T. HUGHES.

The use of diethyl 6-methyl-2-isopropyl-4-pyrimidinyl phosphorothionate, or diazinon for the control of Red Spider Mite (*Tetranychus urticae* Koch) (*T. telarius* L.) on cucumber plants and flies in mushroom houses has made it desirable to obtain information on the magnitude of the residues resulting from its use. This compound, which is effective for the control of a number of insect species and mites, is considerably less toxic than certain other related organo-phosphorus compounds, e.g., parathion, but in the absence of information on the extent of residues likely to occur as a result of its normal application to food crops the Ministry of Agriculture, Fisheries and Food have recommended that there shall be a minimum interval of fourteen days between the last application and the harvesting of the crop. As no such period between application and harvesting is practicable in the use of insecticides or acaricides on cucumbers, it was important to determine the extent of the residues arising from the normal use of diazinon to ensure that no hazard to consumers will result if the interval between application and harvesting is drastically reduced. We have therefore applied diazinon experimentally in cucumber houses by the aerosol method, and have determined the residues on the fruits on the day following treatment to see if the recommendation can safely be modified in this case. In all experiments the residues found were so low that there appear to be no hazards to the consumer under such conditions.

Experimental

Examination of analytical methods

Two methods for the determination of diazinon residues were considered. The diazinon is first extracted from the treated fruit by shaking with a solvent. In the first method proposed by Harris (2) and adopted by Blinn and Gunther (1) for the determination of diazinon residues in milk, the compound is hydrolysed with potassium hydroxide to yield 6-methyl-2-isopropyl-4-hydroxy pyrimidine, which is separated from interfering substances and determined spectrophotometrically at the absorption maximum of 272 m μ .

In the alternative procedure the diazinon is extracted from the solvent with 48% hydrobromic acid, and on boiling this solution the sulphur in the diazinon molecule is converted to hydrogen sulphide which is removed in a stream of nitrogen and absorbed in alkaline zinc acetate solution. The sulphide is determined spectrophotometrically after conversion to methylene blue, as described by Suter, Delley and Meyer (3).

The first method is more elaborate as it requires three separate extraction stages after hydrolysis to isolate the pyrimidine compound and uses up to a litre of solvents in a single determination. In one experiment to investigate the applicability of this method a cucumber (550 g.) was macerated with water (200 ml.) and the resulting mixture divided into two halves. One half was extracted with petroleum ether (b.p. 40°–60°C.), and the extract was concentrated to 50 ml. and subjected to the "clean-up" and hydrolysis procedure described by Blinn and Gunther (1), but using half the stated quantities. To the remaining half, 0.513 mg. of diazinon was added from a standard solution in order to make the diazinon content correspond to that which would result from a residue of 2 p.p.m. in the original cucumber.

The final solutions in 10 ml. ethyl alcohol were examined spectrophotometrically and the spectra are shown graphically (Figure 1). These show that untreated cucumber (Curve A) gives a solution showing considerable absorption over this spectral range with a high blank at the

absorption maximum of 272 m μ . The absorption spectrum obtained from the treated cucumber (Curve B) whilst resembling that from authentic 6-methyl-2-isopropyl-4-hydroxy pyrimidine (Figure 2), is somewhat distorted, but when each value is corrected for the absorption due to the cucumber itself the corrected curve (Curve C) is almost indistinguishable from that obtained with the pure pyrimidine compound.

A calibration line for the pyrimidine compound obtained by plotting absorbance (1 cm.) at 272 m μ against μ g. pyrimidine compound per ml. ethyl alcohol is shown in Figure 3, and the recovery obtained in the cucumber experiment calculated from this curve was 63%.

In two similar experiments where diazinon was added to extracts from macerated cucumber peel and pulp in amounts equivalent to residues of approximately 2 p.p.m., much greater interference was caused by the substrate, as shown in Figures 4 and 5, but the calculated recovery based on the net absorbance at 272 m μ was 60% and 65% respectively.

Although the above method could, with refinements, be used to determine diazinon on or in cucumbers, the high blanks obtained and the large quantities of solvent required rendered it unsuitable for routine use.

Known amounts of diazinon were added to benzene extracts of macerated cucumber equivalent to 0, 3.26 and 6.52 p.p.m. on the original fruit. The extracts were evaporated to 20 ml. in a graduated beaker, 80 ml. of petroleum ether (b.p. 40°—60°C.) were added, and each was extracted in a separating funnel with two 6 ml. aliquots of 48% hydrobromic acid. The resulting extracts were each transferred to a twin-neck hydrolysis flask connected through a condenser to a delivery tube which was dipped into alkaline 1% zinc acetate solution. Nitrogen was passed slowly through the solution from a delivery tube in the other neck of the flask for ten minutes; the flask was then heated and the contents boiled gently for two hours, a slow stream of nitrogen being maintained to carry over all the hydrogen sulphide. The zinc acetate solution was then removed and treated with 0.1% *p*-amino-dimethyl-aniline solution in 1:1 HCl (1.5 ml.) and 0.6% ferric chloride solution in 1:10 HCl (1.0 ml.) The blue colour which formed was measured after not less than 15 minutes at 670 m μ , in a final volume of 10 ml.

A calibration line for diazinon based on inorganic sulphide is shown in Figure 6. This was obtained by adding the previously mentioned reagents to measured aliquots of standardised sodium sulphide solution in a volume of 5 ml., the final volume being adjusted to 10 ml. From this curve the amount of diazinon corresponding to a given absorbance reading may be ascertained, 1 μ g. of sulphur being equivalent to 9.5 μ g. diazinon.

The amounts of diazinon found in the above cucumber extract experiment were 5.6 μ g., 235 μ g. and 542 μ g., corresponding to 0.06 p.p.m., 2.35 p.p.m. and 5.42 p.p.m. respectively. The recovery from the treated extracts amounted to 72% and 83% after making allowance for the blank (Table I).

TABLE I

Diazinon added (p.p.m.)	Diazinon found (p.p.m.)	Recovery (%): inorganic sulphide calibration	Recovery (%): diazinon calibration
0	0.06	—	—
3.26	2.35	72	90
6.52	5.42	83	100

A calibration line for diazinon, obtained by taking known amounts of diazinon and subjecting these to the extraction, hydrolysis and colour development procedure already described, is shown in Figure 6. The recoveries range from 78% to 89% based on the curve prepared from sodium sulphide, with a mean of 81.4%. The recoveries from the previously mentioned additions of diazinon to extracts of macerated cucumbers, when calculated from the calibration line obtained from known amounts of diazinon, were approximately 90% and 100% respectively (Table I).

Estimation of diazinon residues in cucumbers

An aerosol application of diazinon was made in a cucumber house at the rate of 3.3 g./1000 cu. ft. Cucumbers were selected at random (a) immediately before application as a control, (b) on the day following application, and (c) three days after aerosol application. The fruits were weighed and extracted with benzene by surface stripping. The extracts were concentrated to 20 ml. and diazinon was determined by the sulphide procedure as already described.

The results obtained were as follows:—

	Diazinon p.p.m.
Control	0.01
One day after treatment	0.07
	0.11
Three days after treatment	0.11

A second aerosol application was made twelve days later, and three cucumbers were separately extracted and the diazinon residues estimated on the day following treatment. The amounts of diazinon in these cucumbers were found to be 0.05 p.p.m., 0.04 p.p.m. and 0.06 p.p.m.

In a later experiment two batches of twelve cucumbers were selected at random, one before and the other the day following the aerosol treatment of a cucumber house. Six of the untreated cucumbers were peeled and the combined peelings were extracted by shaking for half an hour in benzene, 1 ml./10 g., fruit, and allowing to stand overnight. Two 100 ml. aliquots of the extract, equivalent to 1000 g. of fruit, were evaporated to 20 ml. and examined by the sulphide procedure. The diazinon-treated cucumbers were extracted in two batches of six in the same way. To obtain a measure of the effect of substances naturally occurring in the peel on the estimation of diazinon, additions of diazinon were made to extracts from the peel of untreated cucumbers. These extracts were made with the same proportion of benzene as in the previous estimations and the diazinon was added in amounts covering the range 0 to 0.5 p.p.m., calculated on the weight of fruit from which extracts were made. Recoveries obtained in this procedure ranged from 62% to 98% (Table II).

TABLE II

Diazinon added (p.p.m.)	Diazinon found (p.p.m.)	%
nil	0.03	—
0.12	0.08	66
0.20	0.20	98
0.34	0.30	88
0.41	0.26	62
0.51	0.46	91

The amounts found on the treated fruits and controls were as follows:—

			Diazinon
			<i>p.p.m.</i>
Controls			0.006
„			0.008
Diazinon aerosol applied			
18 hours before sampling			0.265
„	„	„	0.22
„	„	„	0.21

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FIGURE 1. Diazinon analysis—pyrimidine procedure.

U.V. absorption curves obtained from extracts of macerated whole cucumbers.

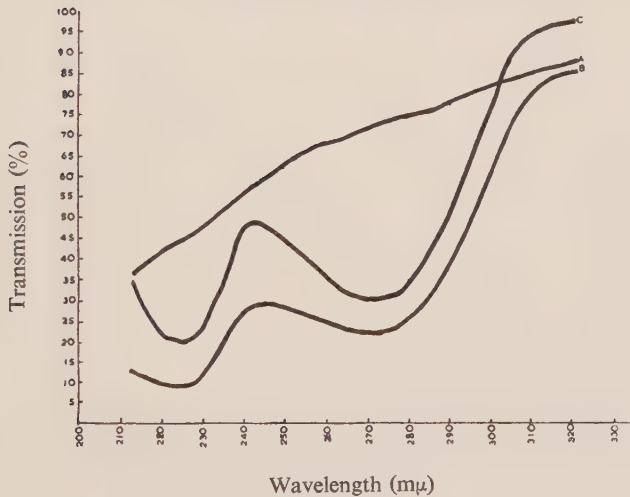


FIGURE 2. Diazinon analysis—pyrimidine procedure.

U.V. absorption curve for 6-methyl-2-*isopropyl*-4-hydroxy pyrimidine in ethanol.

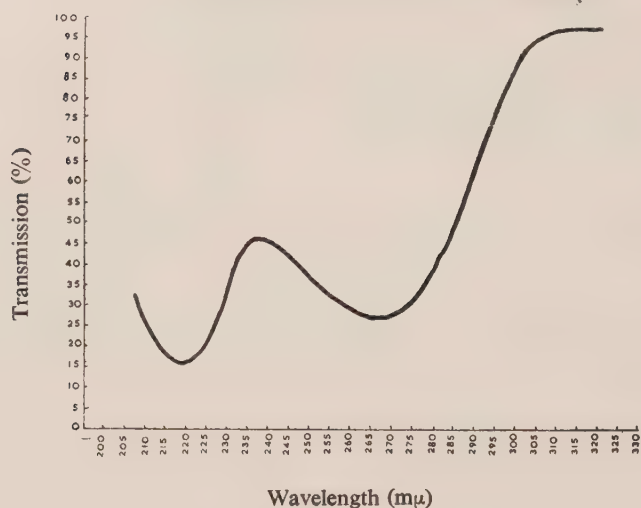


FIGURE 3. Diazinon analysis—pyrimidine procedure.

Calibration line for 6-methyl-2-*isopropyl*-4-hydroxy pyrimidine in ethanol.

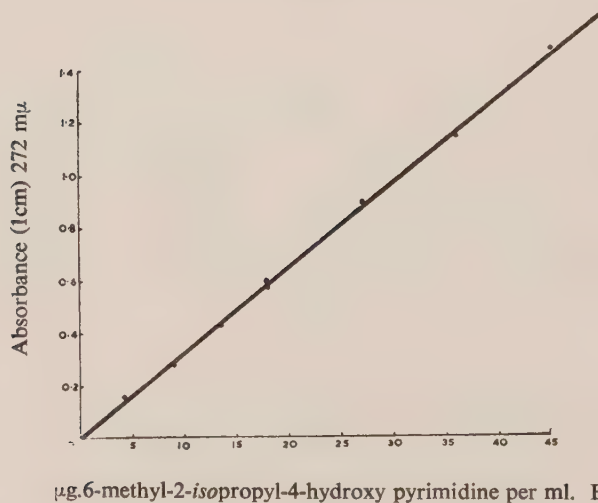


FIGURE 4. Diazinon analysis—pyrimidine procedure.
U.V. absorption curves obtained from extracts of
macerated cucumber peel.

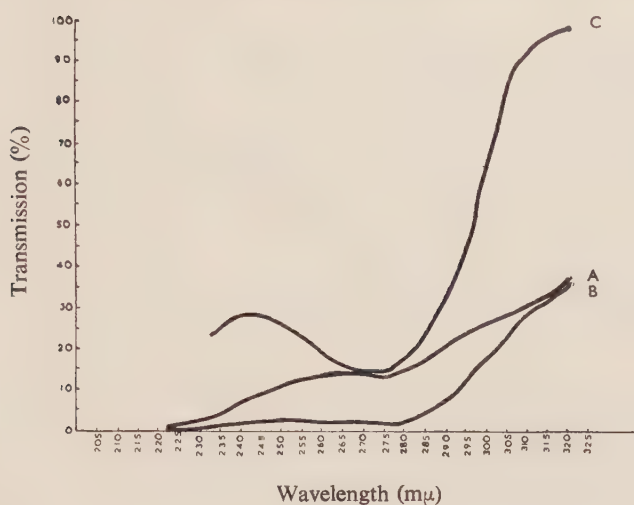


FIGURE 5. Diazinon analysis—pyrimidine procedure.
U.V. absorption curves obtained from extracts of
macerated cucumber pulp.

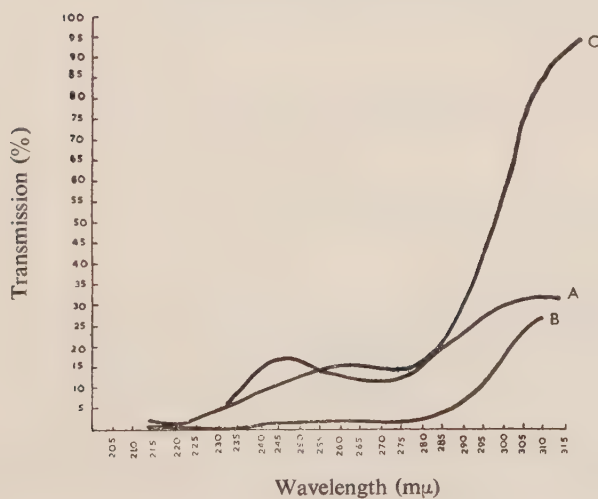


FIGURE 6. Diazinon analysis—sulphide procedure.
Calibration line for sulphide as methylene blue.

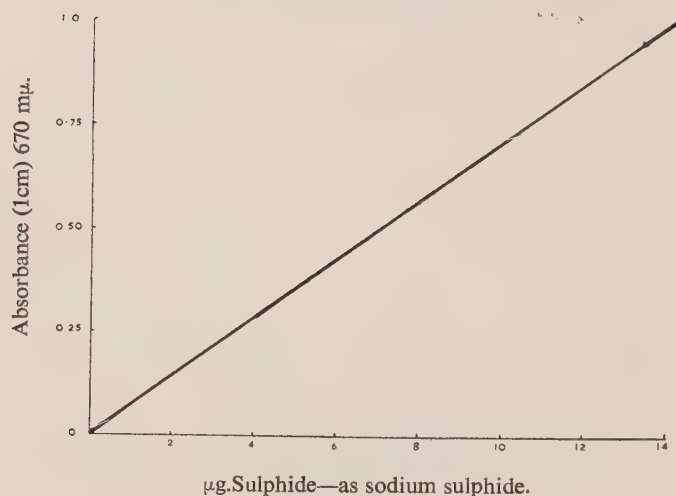
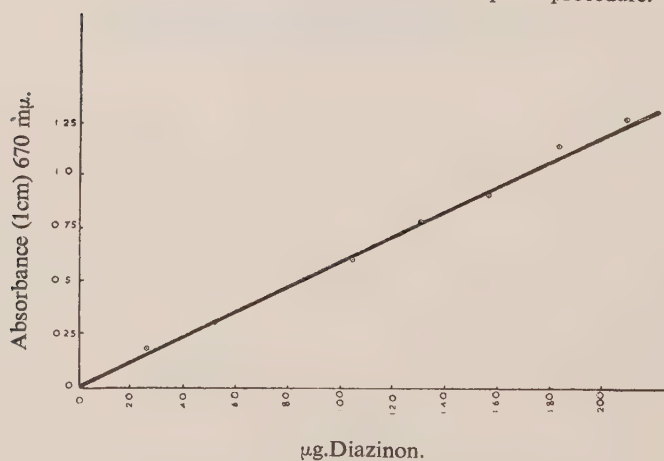


FIGURE 7. Diazinon calibration line—sulphide procedure.



3. EXPERIMENTS ON THE CONTROL OF APHIDS ON LETTUCES WITH FLUORACETAMIDE

by

VALERIE A. GENTLE

The volatility of fluoracetamide, a systemic insecticide, appeared sufficiently high to afford the possibility of employing a fumigation procedure for the control of certain glasshouse pests, in particular, of aphids. A number of experiments were therefore made to examine the effect of the vapour on aphids.

A current of air drawn through crystals of fluoracetamide at a temperature of 17°C. (63°F.) and then over a mixed-age population of the aphid *Aulocorthum solani* at the rate of 0.18 litres per hour for a total of 13 hours had no observed effect on the aphids.

Tests were then made in a thermostatically controlled fumigation chamber in which the fluoracetamide was gently warmed to vaporise it. Lettuce plants infested with *A. solani* were exposed for four hours to a concentration of fluoracetamide equivalent to 1.4 g. (0.05 oz.) per 1000 cubic feet. Few aphids were dead when removed from the chamber, but examination twenty-four hours later showed that complete control of the aphids had been obtained. Slight bronzing of the edges of the leaves of the lettuces was observed twenty-four hours after fumigation. Four days after exposure to this concentration of fluoracetamide vapour the plants showed distinct scorching of the outer leaves.

Similar results were obtained when lettuce plants infested with *Nasonovia ribis-nigri* were subjected to the same treatment.

Attempts to determine the length of time these plants remained toxic to *A. solani* were limited to a period of seven days, owing to the damage to the plants resulting from the treatment. There was, however, a total kill of aphids placed on the plants up to seven days after the fumigation.

The fumigation chamber was cleaned and thoroughly aired between each fumigation experiment, and then tested for cleanliness by exposing aphid-infested lettuces in it for the same length of time as was to be used in the next experiment.

Further tests showed that both *N. ribis-nigri* and *Aulocorthum circumflexum* on lettuces were controlled within three days by exposure for two hours at 60°F. to a concentration of fluoracetamide vapour equivalent to 1.13 g./1000 cubic feet.

Fumigation tests with *A. circumflexum* on detached lettuce leaves at a concentration equivalent to 0.42 g. per 1000 cubic feet for two hours at 63°F. gave 100% kill, and under similar conditions, but at a vapour concentration equivalent to only 0.21 g. per 1000 cubic feet, those aphids on the upper exposed surface died whereas those on the under surface survived.

Tests with *N. ribis-nigri* on detached lettuce leaves showed that 9% survived an exposure of one hour to fluoracetamide vapour equivalent to 0.53 g. per 1000 cubic feet at 59°F.

Trials were made with *N. ribis-nigri* on lettuces which had commenced to heart, and it was found that whereas 0.66 g. fluoracetamide per 1000 cubic feet for three hours killed the aphids on the outer leaves those within the enfolded centre leaves were unaffected, and infestation of these plants increased rapidly after four days.

The systemic properties of fluoracetamide when administered to the soil were investigated by watering lettuces in 5-inch pots with 25 ml. lots of aqueous solutions containing (a) 1 in 1000, (b) 1 in 2,000, and (c) 1 in 4,000 fluoracetamide. These amounts were equivalent to 28, 14, and 7 p.p.m. respectively in the soil. The lettuces were infested with a mixed-age population of *N. ribis-nigri* and were grown at a temperature of 60—65°F. under conditions of low atmospheric humidity. The percentage mortalities of the aphids (Table I) on plants treated with the fluoracetamide solutions were calculated from counts made at intervals after the application of the chemical.

TABLE I
PERCENTAGE MORTALITY OF *N. ribis-nigri* AFTER TREATMENT OF HOST
LETTUCE PLANTS WITH AQUEOUS SOLUTIONS OF FLUORACETAMIDE

Days after treatment	Solution (a)	Solution (b)	Solution (c)
1	72	31	57
2	100	96	75
3	100	97	98
4	100	98.5	99.5

Phytotoxic effects were shown by these plants. Experiments on other plants grown at a temperature of 50–55°F. and at a higher atmospheric humidity, during which 25 ml. of solution ranging from 1 in 1,000 to 1 in 16,000 were watered on the soil in the pots, showed that under these conditions no phytotoxicity resulted. As the highest concentrations of the insecticide failed to control the aphids in this test it is assumed that at lower temperature and higher humidity the uptake of fluoracetamide was insufficiently rapid to produce a lethal concentration within the plants.

Although the tests described were made on lettuces it is stressed that fluoracetamide must not be applied to lettuces grown for consumption as is a highly poisonous compound.

4. RED SPIDER MITE INVESTIGATIONS

by

VALERIE A. GENTLE

Work on the development of a technique for the precise determination of the potency of chemicals towards active stages of Red Spider Mite has been undertaken.

The difficulty of keeping cucumber plants, on which cultures of a number of types of red spider mite are maintained, free from cucumber mildew, led to a number of tests with certain new fungicides synthesised within the Department. It was hoped that these fungicides would prove safe to use on plants where it was necessary to avoid affecting the mite, other effective fungicides proving unsuitable.

The tests showed, however, that when the compounds were used at fungicidal concentrations they had an appreciable acaricidal action and consequently were unsuitable for controlling mildew on experimental cucumbers used for maintaining stock cultures of red spider mite, or on those plants used for testing acaricides.

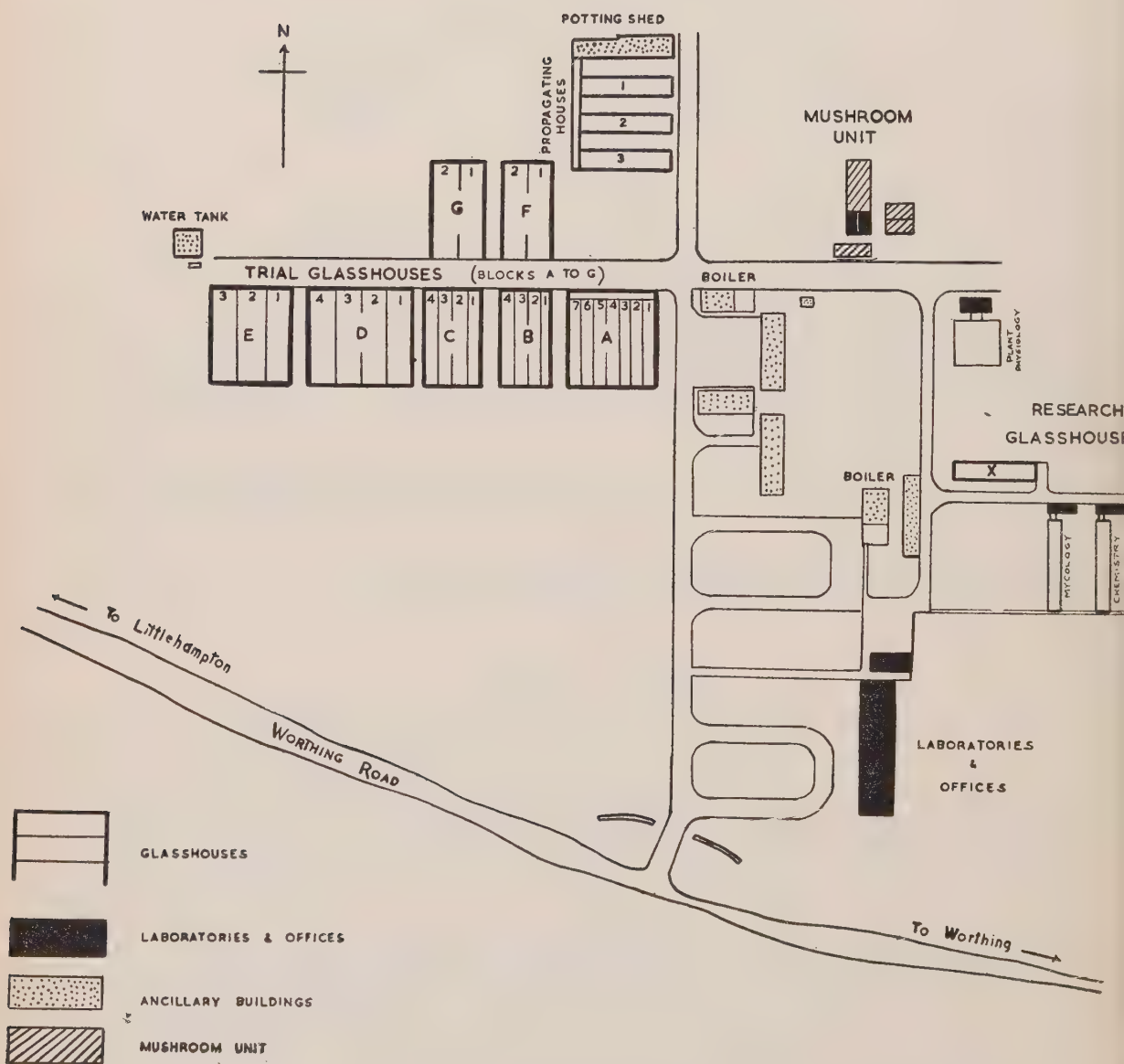
A number of new products were examined for their acaricidal value. None of the compounds tested was of sufficient merit to warrant further trials. Fluoracetamide, which proved a potent aphicide in other trials, did not control red spider mite on French Beans when applied at highly phytotoxic concentrations.

APPENDIX

PUBLICATIONS 1957

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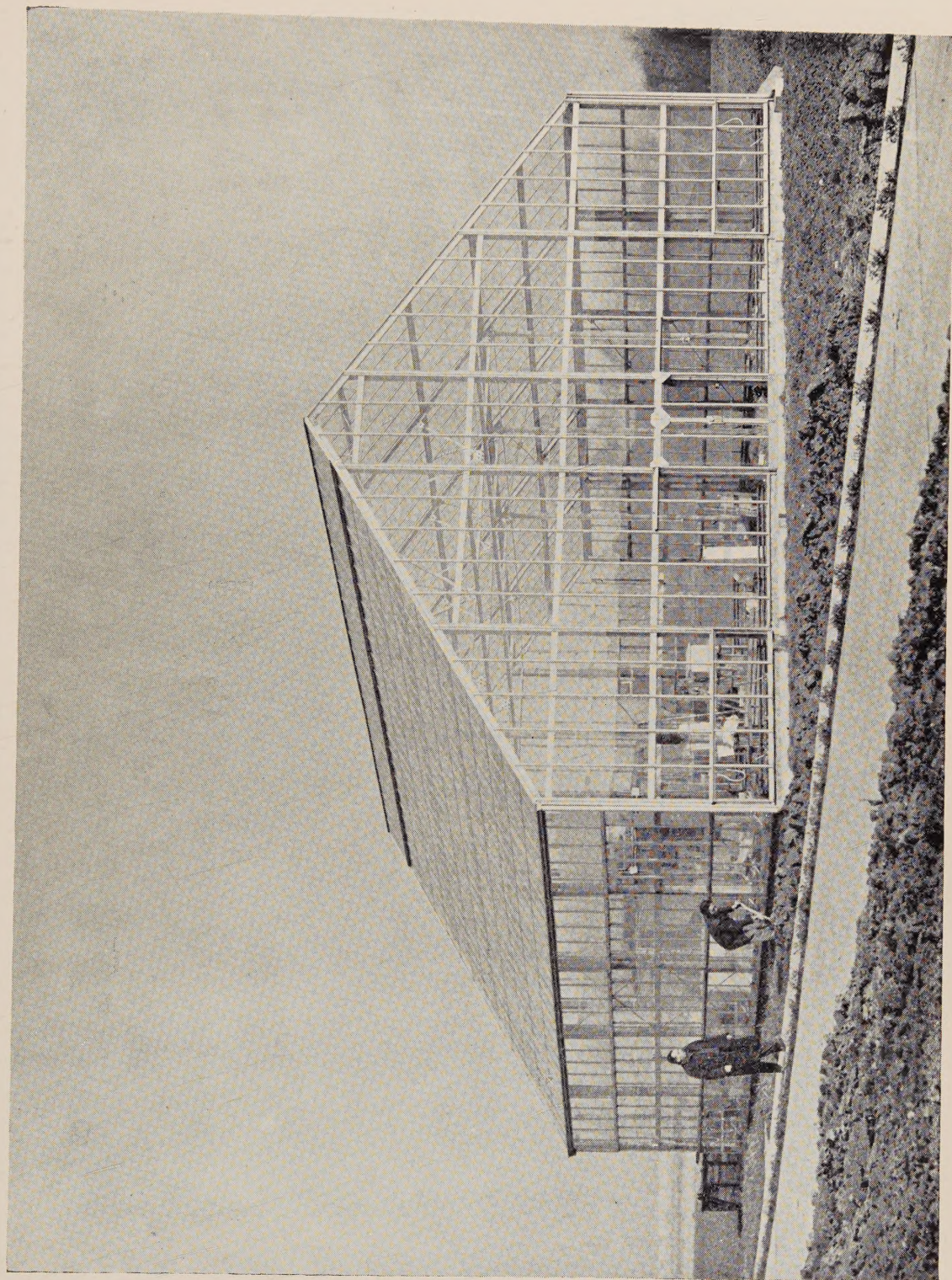
Layout of the glasshouses, laboratories and other buildings

THE JOURNAL OF HORTICULTURAL SCIENCE

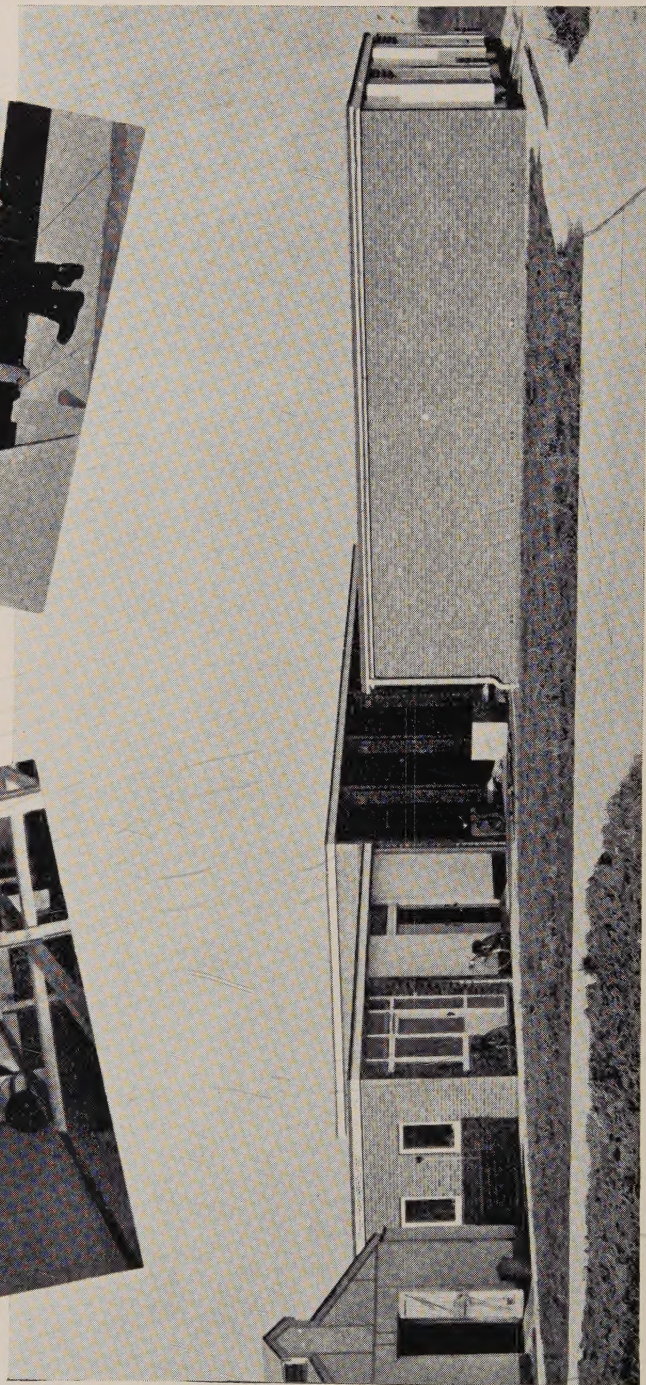
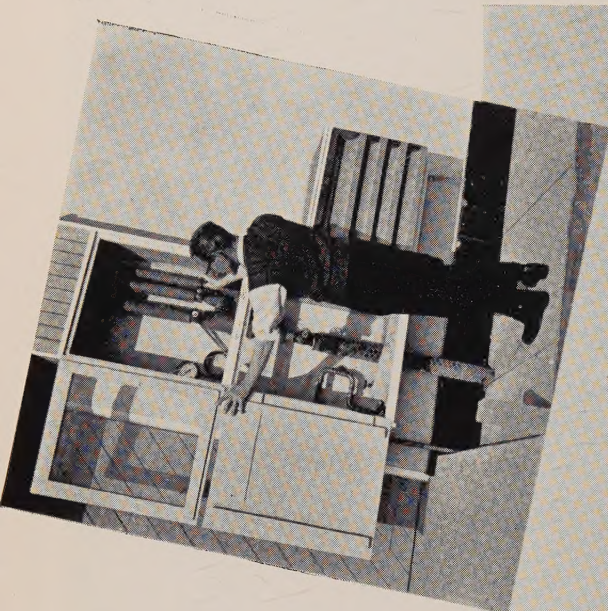
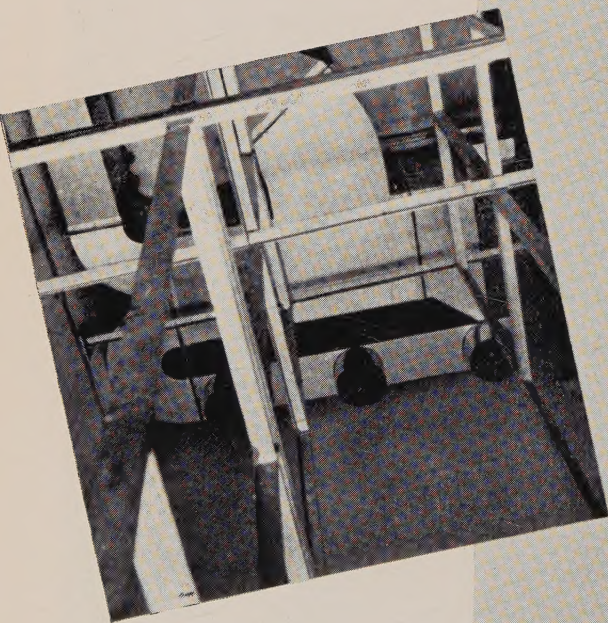
THE JOURNAL OF HORTICULTURAL SCIENCE, which is sponsored by the Long Ashton Research Station and the East Malling Research Station, welcomes contributions on horticultural science from Research Institutes at home and abroad. Papers for publication and all communications should be sent to the Editor at East Malling Research Station, Maidstone, Kent.

Volume 34 (1959) and the previous volume contain papers from both the sponsor Research Stations, and, among others, from the Glasshouse Crops Research Institute, the National Vegetable Research Station, the Scottish Horticultural Research Institute, Wye College and the Plant Pathology Laboratory, Harpenden. Contributions have also been received from Eire, the Netherlands, West and South Africa, Australia and the United States. The list of subjects embraces every aspect of scientific horticulture, including fruit-, vegetable- and flower-growing both in the open and under glass. The current volume is noteworthy for the number of papers dealing with pathological aspects. A series of papers dealing with the growth and cropping of tomatoes under glasshouse conditions is continued in the present volume; others describe experimental work on fruit-tree rootstocks, the effect of shade removal and manuring on cocoa, weed growth, nutrition, irrigation and meteorological factors.

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The plant physiology research glasshouse



The mushroom research unit showing two growing houses to the right with the old Cheshunt shed to the left. In the background is the composting barn with attached stores and field laboratories. The upper photographs show details of the new growing houses, *left*, the main ventilating ducts and tray racks and, *right*, the temperature and humidity controls.